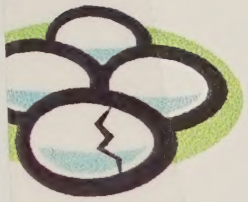
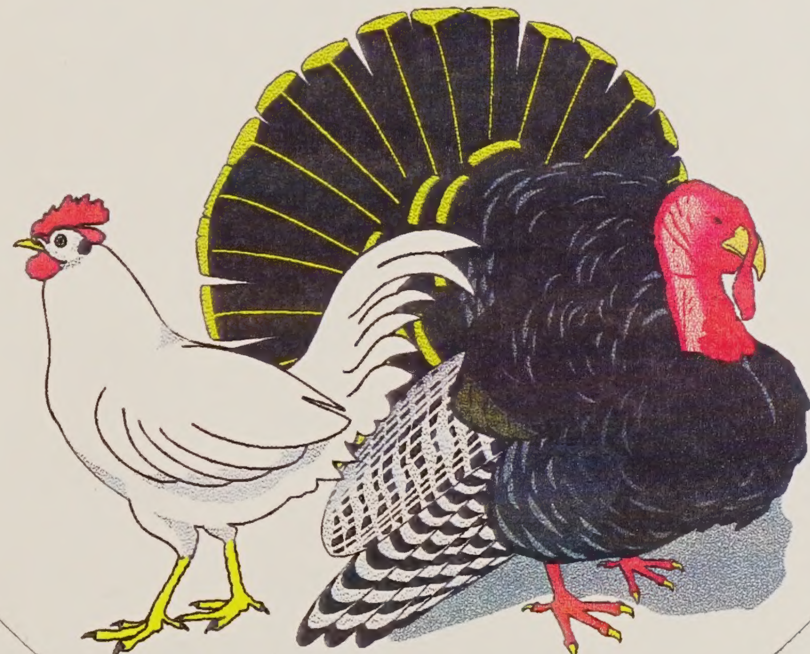


~ TRACE ELEMENTS ~ BYPRODUCT UTILIZATION ~ GROWTH & DEVELOPMENT ~ REPRODUCTION ~ FOOD SAFETY ~ COCCIDIOSIS CONTROL

BELTSVILLE POULTRY RESEARCH DAY

OCTOBER 7, 1997



BELTSVILLE
POULTRY RESEARCH DAY

October 7, 1997
7:30 am - 5:00 pm

Livestock and Poultry Sciences Institute
Beltsville Agricultural Research Center - East
Agricultural Research Service, USDA
Beltsville, MD

7:30 - 8:15 am	**Registration**
8:15 - 9:00 am	**Welcome and Introduction**
9:00 am - 12:30 pm	**Poster Presentations/ On-site Demonstrations** **Coccidiosis control** **Emerging technologies** **Food safety/meat quality** **Reproductive Physiology** **Nutrient utilization & metabolism**
12:30 - 1:30 pm	**Lunch**
1:30 - 2:45 pm	**Industry and ARS Perspectives - Poultry Research, Goals, and Problems (M. Dekich, Carroll's Foods and M. Ruff, ARS)**
2:45 - 3:15 pm	**Coffee Break**
3:15 - 4:45 pm	**Discussion Group** **Problem Solving** **New Technologies** **Regulatory and Food Safety Requirements**
4:45 - 5:00 pm	**Wrap-up**

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Agricultural Research Service

United States Department of Agriculture

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Mission Statement

The goal of the laboratory is to provide the physiological basis for improving reproductive efficiency and enhancing the germplasm propagation of livestock and turkeys. Studies are designed: to develop methods to regulate oocyte maturation, and follicular development; develop and apply knowledge about mediators of pituitary and ovarian hormone action; to identify factors limiting embryonic survival, fertilization rate and overall fertility; to develop methods for long term preservation of sperm and embryos and develop methods to preselect the sex of livestock progeny through the separation of X and Y chromosome bearing sperm. The research encompasses the development of fundamental theory and the implementation of existing knowledge utilizing biochemical, cellular, molecular, and reproduction biotechnology methods.

Research Staff

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*Joined ARS in 1977, published over 160 journal articles, book chapters, and abstracts; invited to over 70 national and international meetings sponsored both by industry and academia; was recipient of the National Turkey Federation Research Award; and, senior editor of "Proceeding-First International Symposium on the Artificial Insemination of Poultry" and it companion laboratory manual "Techniques for Semen Evaluation, Semen Storage, and Fertility Determination".

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*Joined ARS in 1976, has published 130 peer reviewed manuscripts, abstracts, or book chapters. Currently holds a Trust Agreement with a biotechnology company investigating methods of controlling broodiness, and an NRI Competitive Grant to investigate the causes of broodiness.

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Early Embryonic Mortality: A Growing Problem

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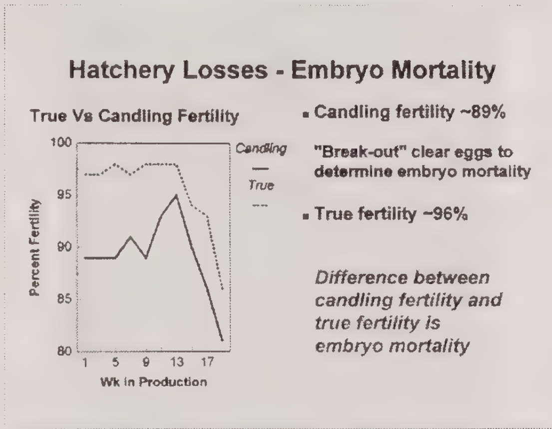
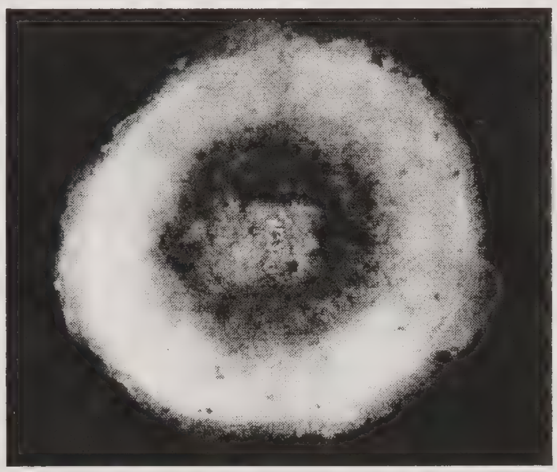
In recent years, the turkey industry averages a 20% loss of all eggs incubated due to hatch failure. While it is known that genetic and management factors influence hatchability, little is know of the physiological basis of hatch loss, particularly early embryonic mortality (prior to the third day of incubation). An informal survey of turkey hatcheries and primary breeders (June 1995) revealed rates of early embryonic mortality ranging from 1% to 15% of the eggs set. Not surprisingly, commercial hatcheries and breeders indicated that early embryonic mortality is a significant and growing problem which needs to be investigated. The higher rates of early embryonic mortality can be attributed to the following: prolonged storage of hatching eggs; an increasing common genetic trait of some "heavy" male lines of unknown etiology; and, possibly the failure of hatchery personnel to correctly differentiate between an early dead embryo and an infertile egg. Our current research objectives include: 1) elucidating the impact of egg handling and storage procedures used by commercial breeders and hatcheries on embryo development; 2) determining if specific genes for programmed cell death (apoptosis) function during early embryogenesis and if they are artificially activated during egg storage; 3) determining molecular mechanisms modulating temperature-induced suppression (cold storage) and activation (incubation) of embryo development; and, 4) determining impact of in vitro semen storage on mechanisms of oviducal sperm storage, fertilization, and early development. The expected results of this research includes increasing the meager body of knowledge regarding factors influencing early embryonic development of the poultry. Such information will provide a rational approach (vs an exclusively empirical approach) to solving the increasingly prevalent problem of embryonic mortality in turkeys, and to a lesser extent, heavy broiler breeders; and the basis for modification of egg handling and storage protocols, and incubation conditions in order to maximize the hatch of eggs set.





This is a turkey embryo from a freshly laid egg. After cold storage the appearance differs, reflecting a loss of embryonic cells.

IMPROVING SEMEN PRESERVATION IN TURKEYS

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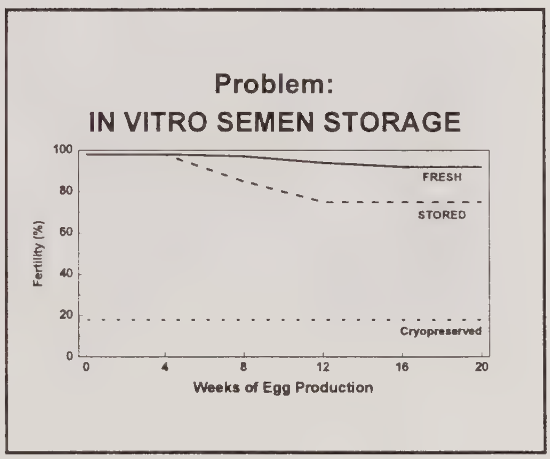
Background: Artificial insemination is a critical component of turkey production as virtually all commercial birds, 300 million annually, are produced in the United States through this technique. Currently turkey semen can be diluted and held up to 6 hours without a decrease in sperm survival or hen fertility. However, extending the interval of short-term liquid storage beyond 6 hours or cryopreserving turkey sperm has not resulted in sperm survival at a level necessary for routine commercial application. If an efficient method of storing semen for at least 24 hours before insemination was developed and utilized, the annual savings to the industry has been estimated at $100 million.

Electron Micrograph of turkey sperm.

Approach: The objectives of this research are to improve methods for preserving turkey sperm in vitro by: 1) developing and optimizing methodologies for short-term preservation of semen in the liquid state for up to 48 hours; and, 2) conducting fundamental research on the cryobiological and physiological factors affecting the cryopreservation of sperm. The specific objectives include: identifying and improving means of sperm evaluation which positively correlate with fertilization and hatchability, and improving conditions for storing sperm in vitro through better understanding of sperm storage in the oviduct (in vivo). Results of this research are establishing how turkey sperm function is compromised during in vitro storage. Such information is providing the basis for the development of diluents and storage procedures specific for long-term preservation of turkey sperm and development of innovative methods to improve the efficiency of artificial insemination in poultry.



Representative weekly fertility with fresh, stored and frozen semen.

IMPROVING EGG PRODUCTION OF TURKEY BREEDER HENS

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Fig 1: Pituitary tissue section from a laying turkey hen. Darkly-stained cells are lactotrophs, which produce prolactin.

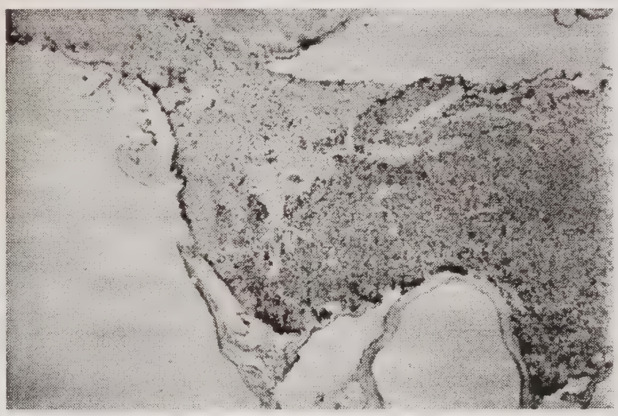


Fig 2: Tissue section from a broody hen. Lactotrophs now populate most of the pituitary. This cellular change results in high prolactin secretion and broodiness.

Turkeys have much poorer egg production and a shorter reproductive season than broiler breeder hens due to basic differences in physiology and genetics. Both species have been selected intensively for growth rate, and the negative genetic correlation between body weight and egg production has reduced their reproductive efficiency. Turkeys exhibit a higher incidence of broodiness than do broiler hens, and turkeys are more likely to quit laying prematurely because light fails to maintain ovarian function. Broodiness likely results in a loss of more than 10 hatching eggs per turkey hen even under good management conditions. Photorefractoriness results in a shortening of the turkey's reproductive cycle and loss of additional egg production. The genetic potential of the turkey hen is undoubtedly much greater than the average production of today's flocks would suggest. Even within today's genetic stock there exist individual hens that do not exhibit broodiness, which lay for an extended season, and produce long clutches of settable eggs. Such hens possess and express a desirable combination of genes which promote egg production, and it is likely that many of these genes influence reproductive efficiency through mechanisms involving hormones. The objectives of this research are to determine how brain and ovarian hormones either maintain or terminate reproduction; to identify key genes which regulate egg laying; and to search for differences in these reproductive genes that could aid in genetic selection. Successful implementation of these strategies will lead to increased average egg production.

New Cukes Boast Higher Beta Carotene

There could be an orange pickle in your future.

Consumers in the United States and in developing countries would gain nutritionally from a pickle that packs beta carotene—the human body's source of vitamin A.

Plant geneticist Philipp W. Simon at ARS' Vegetable Crops Research Laboratory in Madison, Wisconsin, and former University of Wisconsin graduate student John P. Navazio have developed three breeding populations of high-carotene cucumbers. These are the starting materials for vegetable breeding companies to use in developing orange cucumbers.

But the orange color still varies to some extent from plant to plant and from one field or location to another. Says Simon, "We don't always know that these crosses are producing fruit of a different color." He says he still has to slice into the cucumber to see whether or not it has an orange flesh.

But it is certain that Simon has added carotene to a food that otherwise would contain only minuscule amounts of this nutrient. Fruits from Early Orange Mass (EOM) 400 and EOM 402 contain from 1 to 25 ppm (parts per million) total carotene, with an average of 5 ppm.

Now, ARS and the Wisconsin Agricultural Experiment Station in Madison are releasing the germplasm of EOM 400, EOM 402, and Late Orange Mass 404. Simon and Navazio, who is now a vegetable breeder with Garden City Seeds in Victor, Montana, developed these populations by crossing U.S. pickling cucumbers with the *Xishuangbannan* cucumber from the Orient.

Simon is no stranger to genetically altering the color of foods or their nutrient value. In work that started 30 years ago, the late Clinton E. Peterson, an ARS plant breeder, began breeding for darker orange color in carrots. When Simon joined Peterson in 1977, he expanded the effort to laboratory measurement of carotenoid levels, to accelerate the breeding process.

Their work led to a change in the color of carrots from yellow orange to a dark orange and a boost in the carotene level from 70 to 140 ppm. [See "Science in Your Salad," *Agricultural Research,* Oct. 1994, pp. 28.]

Beta carotene, one of more than 600 naturally occurring carotenoids, is found in most fruits and vegetables and converted by the body into vitamin A. Carotenoids, including beta carotene, may reduce the risk of certain cancers and heart disease because of their antioxidant activity.

BRUCE FRITZ

High beta carotene cucumbers have a distinct orange internal color but retain the flavor of traditional green cucumbers. External color is not related to carotene content. (K6081-1)

The Recommended Dietary Allowance for vitamin A for females aged 11 to 51-plus is 800 RE's (retinol equivalents, a unit of vitamin A activity). For males of the same age, the RDA is 1,000 RE's. Meeting these requirements requires 4,800 micrograms and 6,000 micrograms of beta carotene, respectively.

A modest 1-ounce serving of the improved cucumber (with 5 to 25 ppm beta carotene) would contribute 143 to 715 micrograms of the nutrient. This would meet 3 to 15 percent of the RDA for females and 2 to 12 percent of the males'. A 10-percent contribution to the RDA is considered quite good for a food item consumed largely as a relish, condiment, or salad component.

Although at least 5 years away from commercial development, varieties from these new breeding stocks could yield cucumbers and pickles with as much carotene as melons. Home gardeners, as usual, could get the jump on other consumers, since novel vegetable varieties are often first tested in that market.

And while the flavor of an orange pickle would be no different from any other pickled cucumber, its nutritional content would be better, says Simon.

"We were surprised to find that pickles made from these experimental populations retained their nutritional quality. Normally, vitamin C and some B vitamins are lost during food processing."

Until the improved cukes become available, other good sources of vitamin A include yellow and orange squash, sweetpotatoes, tomatoes, and cantaloupe and other melons.

Simon began this research project about 8 years ago. Partial funding was provided by the Pickle Seed Research Foundation in St. Charles, Illinois.—By **Linda Cooke,** ARS.

Philipp W. Simon is at the USDA-ARS Vegetable Crops Research Laboratory, 1575 Linden Drive, University of Wisconsin, Madison, WI 53706; phone (608) 264-5193, fax (608) 262-4743. ◆

SCOTT BAUER

A Breakthrough for Turkey Growers

Biological Basis for Broodiness

If you think selecting and cooking the traditional Thanksgiving turkey is a chore, consider the trials of the turkey producer.

First, the turkey is hardly the most fecund of barnyard creatures.

A turkey hen typically doesn't begin laying eggs until she's 30 weeks old and then produces only 90 eggs over a 25-week laying season. That's a poor showing against meat-type chickens, which begin laying at 23 weeks—or egg-type hens, which will lay for a year or more and produce as many as 285 eggs annually.

To add to the turkey grower's woes, there's broodiness—a sort of reversion to behavior of birds in the wild, when the turkey decides she wants to sit and hatch her eggs, instead of continuing to produce more.

That's where John Proudman comes in. "The problem is a hormone called prolactin," explains Proudman, a poultry physiologist with ARS' Germplasm and Gamete Physiology Laboratory at Beltsville, Maryland.

"When a good turkey layer is producing an egg a day, prolactin levels in the bird's blood are perhaps 150 nanograms (billionths of a gram) per milliliter of blood. But when a bird goes broody, prolactin levels may be up to 10 times as high, and egg production drops to zero.

"We've calculated that if we could get around this problem and increase turkey egg production by just 10 eggs per hen, it would be worth another $30 million a year to the turkey industry," says Proudman.

Turkey eggs are far from a sure bet to become gobblers, at any rate. U.S. growers raise about 4 million turkey breeder hens annually, which in turn produce 308 million turkey poults (chicks), of which only 292 million make it to market.

The turkey hen with lower levels of prolactin may visit her nest once or twice a day, spending the bulk of her time elsewhere. But the broody bird stays on the nest all day long, warming her hoarded eggs.

Driven by Brain Chemistry

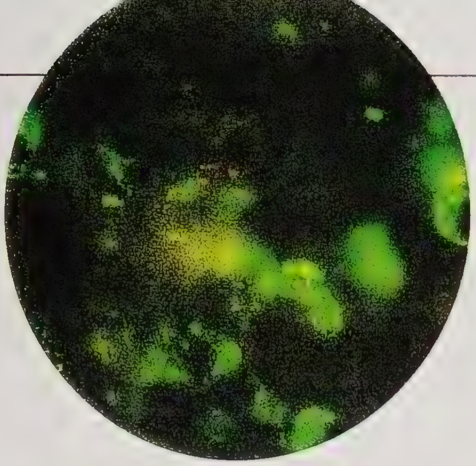
That prolactin is the culprit is not in question. Studies by University of Minnesota scientists have shown that if a bird is physically primed to lay eggs but is injected with prolactin, that bird will go broody.

Nature provides turkeys with prolactin via the pituitary gland. Certain cells in the hypothalamus region of the bird's brain produce a natural chemical called vasoactive intestinal peptide, or VIP. This VIP travels to the pituitary gland, where it stimulates cells called lactotrophs to produce prolactin.

The turkey pituitary gland is also home to cells called somatotrophs, responsible for production of growth hormone. Unlike the human pituitary gland, where lactotrophs and somatotrophs are intermingled, in the turkey pituitary the two types of cells normally keep to their own territory—lactotrophs up front, somatotrophs mostly in the rear.

But if the lactotrophs and somatotrophs don't share neighborhoods, they do share something more surprising: function.

"As hens become broody, you can see some of the same cells producing both growth hormone and prolactin,"



Turkey pituitary cells were stained to identify growth hormone (green) and prolactin (red). Photomicrograph by John Proudman.

reports Proudman. "The lactotrophs no longer keep to their own territory; the cells in the rear begin producing prolactin where growth hormone was previously produced.

"Studies about 10 years ago with rats showed that such cells could alter function during physiological changes such as pregnancy. But this is the first time this change in cell function has been seen in birds. It could help explain the large increases in prolactin present in some birds."

Proudman and other scientists hope to curtail the potential flood of prolactin in the broody bird in several different ways.

In collaboration with poultry physiologist Wayne Kuenzel at the University of Maryland, Proudman is studying the pituitary to see what triggers a cell to switch jobs from growth hormone production to prolactin production—perhaps a natural "on-off" switch in the genes that dictates a cell's assignment.

Interrupting the Message

The researchers are looking for the receptors where prolactin congregates to wield its influence.

"We know there must be prolactin receptors on the turkey's ovary because if you give a bird prolactin, its follicles regress and it stops producing eggs," says Proudman.

"But there are undoubtedly receptors in other tissues as well. We've cloned and worked out the DNA sequence for the prolactin-receptor gene. And we've gone on to find the messenger RNA that would carry the code to a cell to be a receptor in tissues in the ovary, kidney, and pituitary gland," he says. "If the RNA for a receptor protein is present in the tissue, we know that tissue is likely to bind prolactin."

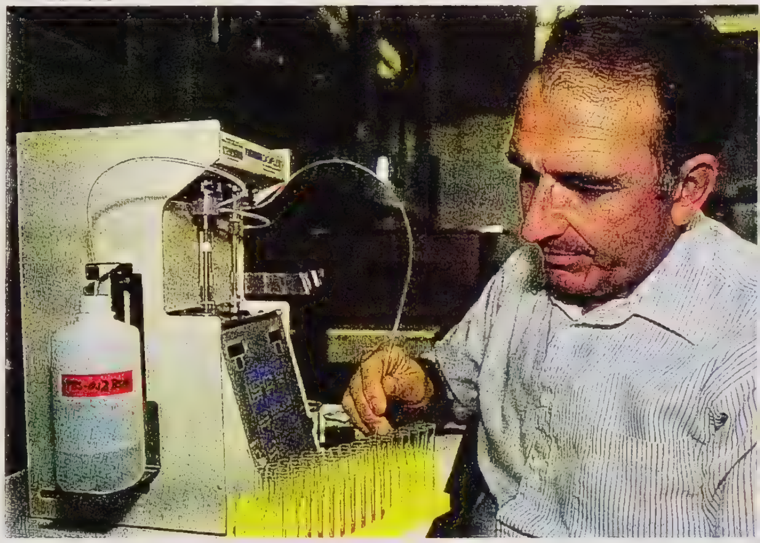
The scientists will also tackle the question of what stimulates VIP production in the bird's brain, triggering the chain of events that leads to a surfeit of prolactin in the broody turkey.

One potential solution is antisense technology—finding the gene that carries the *sense* of the code for production of prolactin, then creating another gene that carries an opposite message, or *antisense,* to block prolactin production. Just such a gene has been developed by molecular biologist Eric Wong of Virginia Polytechnic Institute and State University at Blacksburg, Virginia.

Proudman has collaborated with Wong, Bernard Wentworth of the University of Wisconsin, and Mohamed El Halawani of the University of Minnesota to produce turkeys that carry this antisense gene. The true test will come when those turkeys' offspring reach egg-laying age and are at risk for broodiness.

"We did in vitro work with pituitary cells that showed you can use antisense RNA to block the prolactin stimulation normally seen with VIP, without suppressing the base levels of prolactin," says Proudman.

KEN HAMMOND



Using a pipette, poultry physiologist John Proudman draws off samples from tissue culture for radioimmunoassay of turkey hormones, such as prolactin. (K7000-1)

Research has also revealed another piece of the puzzle: prolactin protein variations known as isoforms, which can be sorted on the basis of their molecular weight and electric charge.

"There are different amino acids that make up prolactin molecules and have different natural electric charges, positive or negative," says Proudman. "When we tested blood from broody birds, concentrations of some prolactin isoforms were apparently so low that we couldn't detect them.

"We might be able to trace the genes involved in producing different types of prolactin molecules and then perhaps use those genes as markers for broodiness when we select birds for breeding."—By **Sandy Miller Hays**, ARS.

John A. Proudman is at the USDA-ARS Germplasm and Gamete Physiology Laboratory, Bldg. 262, Room 305, 10300 Baltimore Ave., Beltsville, MD 20705-2350; phone (301) 504-8094, fax (301) 504-8546. ◆

Carrying New Vaccines to Newcastle

KEN HAMMOND

Prior to hatching, veterinary medical officer Henry Stone vaccinates white leghorn eggs with an oil emulsion vaccine against Newcastle disease. (K7001-1)

Foreign and domestic strains of Newcastle disease virus rank among the most dangerous economic threats to U.S. broiler and egg industries. But two kinds of experimental vaccines represent scientific firsts that offer new options to producers.

Henry D. Stone, an ARS veterinary medical officer, developed the vaccines over several years at the Southeast Poultry Disease Research Laboratory in Athens, Georgia. ARS is seeking patent protection. Further studies are under way in cooperative research and development agreements (CRADA's) with vaccine producers.

Newcastle virus was discovered in 1926 in Indonesia and near Newcastle-on-Tyne, England. Highly contagious, it can attack chickens, turkeys, parrots, partridges, cormorants, ostriches, and other wild and pet species. Typically, infected birds act fidgety, have trouble breathing, or have swelling around the eyes.

Deadly strains usually damage a bird's heart, liver, kidneys, brains, and intestines. But sometimes the only sign is depression, quickly followed by death.

USDA's Animal and Plant Health Inspection Service quarantines all legally imported birds that can carry the disease, until they're shown to be healthy. But smuggled birds and migrating waterfowl have introduced the deadly Newcastle strains known as velogenic viscerotropic or velogenic neurotropic. The former affects birds' inner organs, or viscera; the latter gravitates to the nervous system.

In 1971, pet birds from Latin America caused the only major U.S. outbreak. It infected broiler chicken and egg operations in California's San Bernardino Valley. Eradication took 2 years. To deprive the virus of hosts, 11 million poultry and other birds were destroyed within a quarantine zone covering 45,000 square miles.

While vaccination may keep a chicken free of symptoms, it won't prevent infection. And healthy-looking vaccinated chickens can still shed virus in their feces, sparking new outbreaks.

Newcastle vaccines use one of two kinds of antigen. The antigen triggers the bird's immune system to make antibodies to stop virus particles from latching onto cells. Newcastle antigen may be a live, weak virus strain—which sometimes causes disease—or an inactivated, "dead" virus.

Some producers prefer a dead-virus vaccine. They also prefer to vaccinate poultry early in life, to give the virus a smaller window of opportunity. The earliest vaccine is the in ovo, or "in egg" type. It is injected through the eggshell into the embryo. ARS scientists in East Lansing, Michigan, pioneered development of in-the-egg vaccines several years ago.

"When you inject a batch of grown chickens, a few usually squirm away and manage to avoid getting their shot, or a full dose," Stone says. "In ovo is much easier, and every bird gets vaccinated."

But today's in ovo vaccines use live-virus antigen. Stone's version would be the first to use inactivated virus. "Adapting a dead-virus Newcastle vaccine for commercial egg-injection machines would save much time and labor for producers who prefer not to use live-virus vaccines."

In a series of tests in a quarantine laboratory, Stone injected many groups of 18-day-old White Leghorn chicken embryos with varying doses of the experimental in ovo vaccine. Stone then exposed vaccinated and unvaccinated birds to a live, deadly strain of Newcastle virus 53 days after hatching.

All the unvaccinated birds died, but no disease symptoms appeared in any vaccinated birds. Stone found

Agricultural Research Service

United States Department of Agriculture

Growth Biology Laboratory

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Mission Statement

The mission of the Growth Biology Laboratory is to: 1) examine pre- and post-translational genetic determinants that influence nutrient utilization for lean tissue deposition by livestock; 2) determine practical approaches to implement near-market technologies affecting fat:protein ratio into livestock production agriculture; 3) optimize and validate nondestructive techniques for the prediction of live animal composition; and, 4) assess nutrient/management variables and metabolism modifiers on target animal health, well-being, product quality and safety.

Research Staff

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Major Research Interests: 1) Physiological factors regulating growth and metabolism in poultry, with emphasis on hormonal regulation of compensatory growth in broilers, 2) Development of immunodetection methods for polyamines and biogenic amines in animal feedstuffs, 3) Peripheral factors regulating appetite in poultry.

Education and Expertise: May Institute for Medical Research, Cincinnati, Research Associate, 1976-79; University of Hawaii, Post-Doctoral Fellow, 1974-79; Purdue University, Ph.D., Animal Physiology, 1970-74; University of Missouri, M.S., Dairy Husbandry, 1968-70; University of Missouri, B.S., Animal Science, 1964-68.
*Joined ARS in 1979 and has published over 250 peer reviewed manuscripts, abstracts or book chapters. Served as Section Editor, Physiology and Reproduction, *Poultry Science*, 1994-96. Recipient of two BARD research grants and an OECD research and travel grant. Adjunct Associate Professor, University of Delaware. Currently holds two patents and a CRADA which are related to investigating the role of insulin-like growth factors in poultry growth and metabolism.

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Major Research Interests: Developing, evaluating and refining techniques for in vivo determination of body composition of swine and poultry.

Education and Expertise: Department of Animal Science, North Dakota State University,- Research Associate, 1981; Metabolism and Radiation Research Laboratory, USDA-ARS, Research Physiologist, 1979; Department of Pathology, Medical School, University of Wisconsin, Postdoctoral Fellow, 1976; University of Wisconsin-Madison, Ph.D. Nutritional Science, 1976; Colorado State University, M.S. Animal Nutrition, 1969; Colorado State University, B.S. Animal Production, 1963.
*Joined ARS in 1983, has published over 130 peer reviewed manuscripts, proceedings or abstracts.
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Major Research Interests: Regulation of feed intake and energy balance in poultry, especially the study of peripheral factors (hormones) that regulate feed intake in birds.

Education and Expertise: University of Wisconsin, Madison, WI, Postdoctoral Fellow, Department of Biochemistry, 1977-1979; Rutgers University, New Brunswick, NJ, Ph.D. Nutritional Biochemistry, 1977; Rutgers University, New Brunswick, NJ, B.S. Agricultural/Animal Science, 1973.
*Joined ARS in September 1979 and has published over 120 peer reviewed manuscripts, abstracts or book chapters.

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Major Research Interests: Control of avian lipid metabolism; Regulation of appetite in poultry to enhance consumption of diets containing less than optimal levels of crude protein.

Education and Expertise: University of Kentucky, Ph.D. Nutrition and Biochemistry, 1976; University of Kentucky, MS Physiology, 1974; University of Kentucky, BS Animal Sciences, 1966.
*Joined ARS in 1976, named recipient of 1996 Nutrition Research Award, given by American Feed Industry Association. Has published over 250 peer reviewed manuscripts, abstracts, proceedings or book chapters. Currently developing a Trust Agreement with Igene in Columbia, MD for a carotenoid produced through a proprietary fermentation process.

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[illegible] Laboratory, 1979, ABS;
[illegible], MD 20705. Phone (301) [illegible].

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[illegible] of [illegible] in [illegible] study, [illegible] results [illegible]

[illegible] Rutgers University, New Brunswick, NJ [illegible]

[illegible] 1979 [illegible] published [illegible]

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UNDERSTANDING THE ENDOCRINE REGULATION OF PROTEIN AND FAT DEPOSITION IN CHICKENS AND TURKEYS

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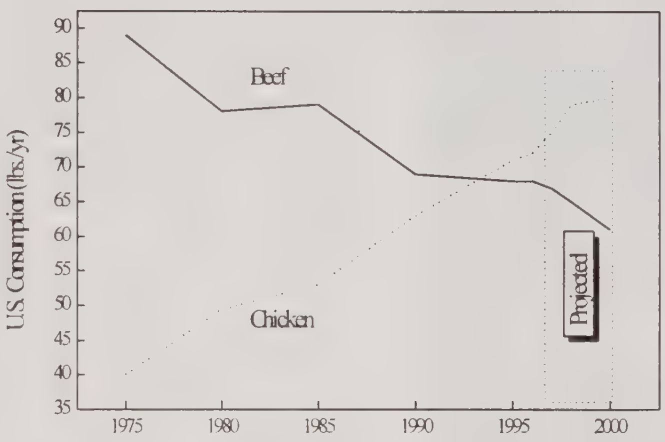

The fastest growing segment of animal agriculture is that of poultry meat production. The poultry industry sold products worth $18.6 billion in 1995. Selection for growth rate and efficiency has resulted in negative complications, such as ascites, reduced reproductive efficiency, skeletal abnormalities, and increased carcass fatness. The disruption of physiological homeostasis may present economic as well as genetic barriers to further progress in improving growth and efficiency. Little information is available on how to ameliorate these growth related problems. Research on the endocrine mechanisms controlling growth and metabolism as it relates nutrient partitioning is currently being conducted. Specifically, we are: 1) identifying genes and gene products associated with muscle growth and fat deposition, 2) investigating the endocrine adaptations to early-in-life feed restriction, and how changes may ameliorate some of the negative conditions inherent to rapid growth, 3) identifying peripheral factors involved in regulating feed intake. The information gained from this research will provide a basic understanding of the endocrine regulation of metabolism and ways to maximize genetic potential, while overcoming the physiological imbalances of rapid growth.

BODY COMPOSITION ANALYSIS OF POULTRY

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A major deterrent to reducing fat and increasing protein, is a lack of nondestructive techniques to assess dynamic changes in body composition of animals, which restricts our ability to design production systems that efficiently produce animal products of optimal composition. Thus, there is a need for validated and standardized direct and indirect nondestructive techniques for determining body composition and methods are needed to quantitate in situ metabolism of targeted tissues. The purpose of this study is to evaluate techniques that will allow repeated directed measurements of fat mass, lean body mass and bone mineral content of the live animal.

Dual energy x-ray absorptiometry **(DXA)**, although a relatively new technique for measuring body composition of humans, is rapidly being accepted as the "gold standard". Based on the relative attenuation of x-rays at two discrete energy levels, it provides a measure of bone, fat and lean tissue masses. The single most powerful technique for studying composition of the live animal is MRI. Magnetic resonance imaging **(MRI)** provides excellent contrast images that allows the visualization and measurement of fat, muscle and various other organs. This is accomplished by placing the anesthetized animal within a high magnetic field and exciting the tissues with radio frequency waves. Total body electrical conductivity **(TOBEC)** measures the energy absorption in the presence of a radio-frequency electromagnetic field, which is calibrated internally to match the response of a conductivity sensing element. Since the energy is absorbed more in somewhat conductive material (lean tissue) than in less conductive material (fat tissue), TOBEC produces a signal (phase response) that is proportional to the lean mass of the animal.

The MRI instrument is very expensive to purchase and operate, thus, its use is limited to research purposes. The DXA is inexpensive to operate, but the cost, although much less than the MRI, is enough that use would be limited primarily to large production units, cooperatives or research facilities. Thus, producers could ultimately benefit from more accurate assessment of superior breeding stock. This technique could also find application in the evaluation of valuable animals developed through transgenic research. TOBEC is relatively inexpensive, small (portable) and simple to operate, but requires extensive calibration - may be appropriate for field studies.

[illegible]

Alvin D. Mitchell
Growth Biology Laboratory
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A major key to reducing fat and increasing [illegible] is the [illegible] of noninvasive techniques to measure dynamic changes in body composition of animals, which requires our ability to design production systems that efficiently produce animal products of optimal composition. Thus, there is a need for validation and calibration of direct and indirect noninvasive techniques for determining body composition, and methods are needed to quantitate in vivo mineral mass of targeted tissues. The purpose of this study is to evaluate techniques that will allow enhanced in vivo measurements of fat mass, lean body mass and bone mineral content of the live animal.

Dual energy X-ray absorptiometry (DXA), although a relatively new technique for measuring body composition in humans, is rapidly being accepted as the "gold standard". Based on the relative attenuation of X-rays at two distinct energy levels, it provides a measure of bone, fat and lean tissue mass. The single most powerful technique for studying composition of the live animal is MRI. Magnetic resonance imaging (MRI) provides excellent contrast images that allows the visualization and measurement of fat, muscle and various other organs. This is accomplished by placing the anesthetized animal within a high magnetic field and bombarding the tissues with radio frequency waves. Total body electrical conductivity (TOBEC) measures energy absorption [illegible] frequency electro[illegible] field which is calibrated internally to match [illegible] of [illegible] Since the energy is absorbed more in [illegible] than in less conductive material (fat tissue), [illegible] proportional to the lean mass [illegible] thus, its use is [illegible] cost [illegible] less than MRI is enough that use would be limited primarily to large production and cooperative research facilities. Thus, producers could ultimately benefit from [illegible] of [illegible] this technique could give [illegible] animal [illegible] through transgenic research [illegible] to operate [illegible] for field

MINERAL METABOLISM IN THE AVIAN EMBRYO

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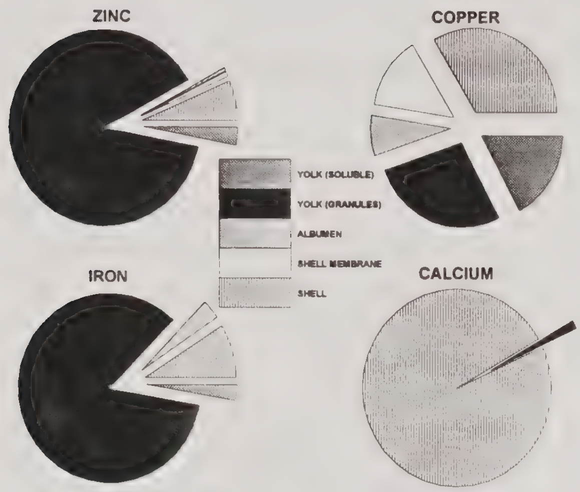

Figure 1. Mineral distribution among different fractions of the turkey egg.

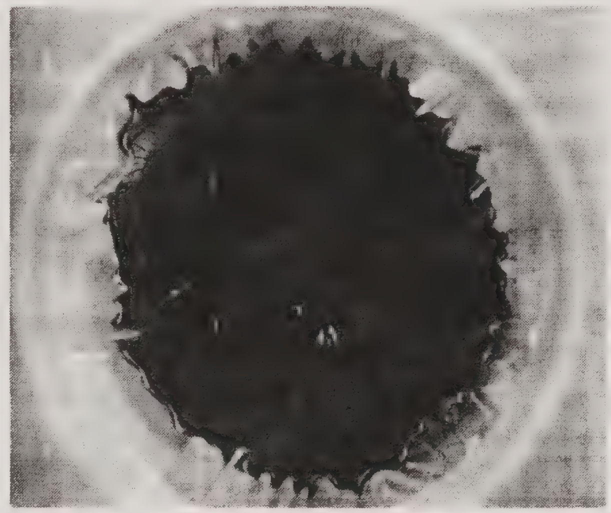

Figure 2. Sixteen day-old turkey embryo maintained in long term shell-less culture.

Background: Proper mineral nutrition is crucial to embryonic growth and survival. An inadequate supply of certain essential minerals can result in poor growth, abnormal development and, in severe cases, embryonic death. To improve hatchability, we must understand the role of mineral nutrition in embryonic development. Since the entire store of nutrients required for hatching is deposited in the egg at the time of its formation, we must also understand the processes of mineral deposition into the egg.

Research Goals: 1) To study the transfer of minerals from tissues of the laying hen to specific portions of the egg. 2) To study mineral uptake and metabolism in selected tissues, cultured cells and blood obtained from embryos at different stages of development. 3) To examine the relationship between changes in metalloprotein levels and changes in tissue and blood mineral levels as a function of stage of development. 4) To study the role of the yolk sac in mineral uptake and metabolism by the embryo.

Approaches: Laying turkey hens were used to investigate mineral deposition into the newly formed egg. Turkey eggs were chemically analyzed to determine their mineral composition and distribution (Figure 1). Turkey embryos were studied both in the egg (*in ovo*) and outside of the egg (*ex ovo*) in long-term shell-less culture (Figure 2) to determine aspects of mineral uptake and metabolism throughout development.

Accomplishments: 1) Vitellogenin, a yolk precursor protein manufactured by the liver of the laying hen is the major route for mineral deposition into the yolk of the egg. 2) Specific metal-binding proteins isolated from liver and yolk sac play important roles in tissue uptake, storage and transfer of minerals during embryonic development. 3) The yolk sac plays a key role in the mobilization of egg yolk mineral stores.

Future Research Plans: Investigate specific factors that regulate feed intake in chickens with the goal of being able to manipulate this process to decrease carcass fat and enhance lean body mass accretion during post-hatching growth.

USING BOTH CRUDE PROTEIN AND SUPPLEMENTAL DIETARY TRYPTOPHAN TO REGULATE FEED INTAKE AND GROWTH BY REGULATING TISSUE NEUROTRANSMITTER LEVELS

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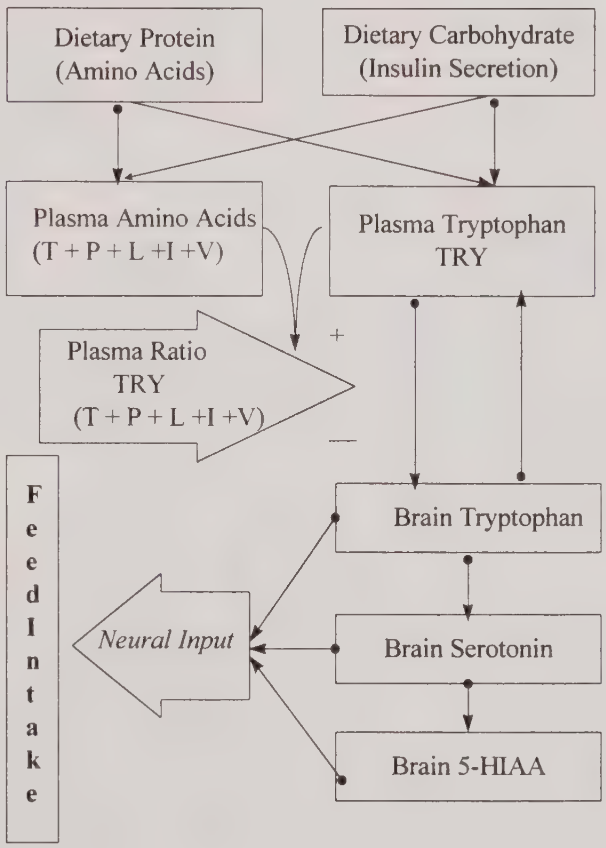
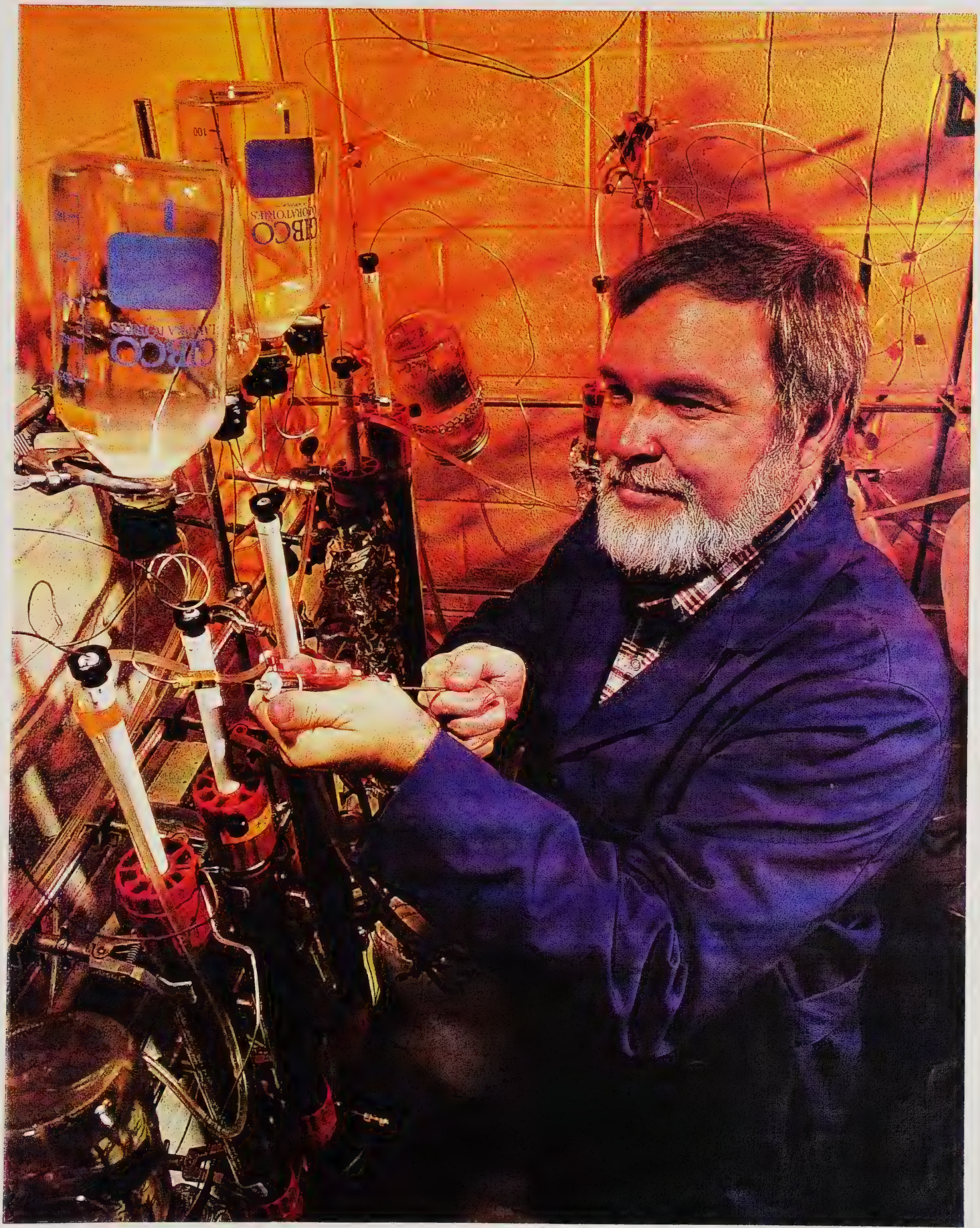


The greatest single cost in the production of the modern broiler is feed. It has been estimated that over 70% of this cost can be attributed to feed. In turn, the most expensive dietary component is protein. Controlling the cost of this input involves understanding both the roles of protein *per se* and of specific amino acids in regulating protein and fat synthesis in the broiler. It is well known that a narrow ratio of dietary energy to protein, or possibly specific amino acids, promotes rapid growth and a lean broiler carcass. Defining limiting amino acids as regulators of particular biochemical steps allows the producer to tailor diets according to particular age-specific metabolic needs. We, fed moderately low protein diets, but have supplemented these diets with the amino acid tryptophan. Central nervous system activity was monitored by measuring the levels of certain neurotransmitters implicated in food intake regulation.

- Tissue tryptophan levels regulate consumption of low protein diets, but not of high protein diets.
- Understanding the role of amino acids in modulating feed intake through the activity of the central nervous system would allow the feeding of apparent sub-optimal levels of crude protein.

SCOTT BAUER



Microbiologist Jim Hunter collects a gas sample from a trap placed in the outflow line of a test column filled with soil, contaminated water, and a small amount of vegetable oil. If bacterial action has begun denitrifying the water, nitrous oxide will be present. (K5880-2)

WHERE'S THE Fat?

Noninvasive body scans tell what type of weight is being gained.

No one could call Al Mitchell's Sundays relaxing.

First, there's the task of negotiating a truckload of a dozen or so hefty hogs through downtown Washington, D.C., traffic. Then, Mitchell gets to help lift each of the hogs onto a high table—twice—at their destination, before heading home with his squealing load at the end of a long, long day.

Mitchell's no moonlighting hog farmer; he's an animal scientist with USDA's Agricultural Research Service.

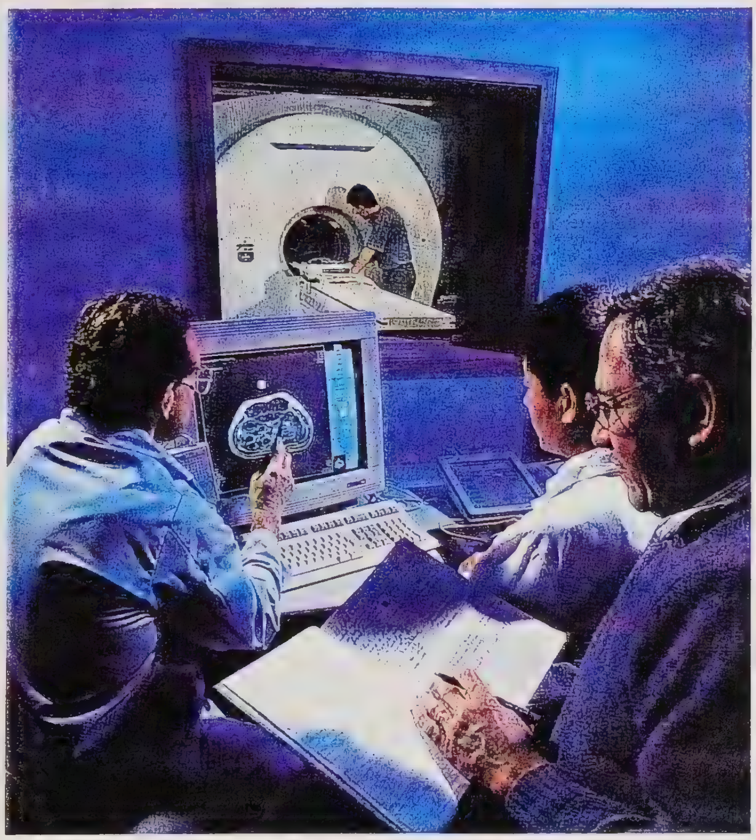
An even bigger surprise is the hogs' destination on their Sunday jaunts: Howard University, where they undergo magnetic resonance imaging (MRI)—the same high-tech procedure medical doctors use to detect internal disorders such as brain tumors in humans.

Since 1985, Mitchell has collaborated with Paul Wang of Howard University on using MRI's to analyze body composition of research hogs while they're still on the hoof.

The sharp images of the MRI's let scientists see how a particular swine breeding line looks—in terms of fat-to-lean ratio, or how a particular diet is affecting an animal's body—and still use that animal for further research.

"Before MRI's, there really was no accurate way of measuring the body composition of a live animal," explains Mitchell, who is with the ARS Growth Biology Laboratory at Beltsville, Maryland. "The MRI provides a lot of information you can't get with other techniques, such as the amount of fat on the animal, the distribution of that fat, or the volume of muscle in specific muscle groups.

SCOTT BAUER



At Howard University in Washington, D.C., chemist George Gassner records information as animal scientist Al Mitchell (left) and university scientist Hua Fu Song examine a cross-sectional magnetic resonance image from the abdominal area of a pig. In the background, animal geneticist Armin Scholz monitors the pig within the MRI chamber. (K5906-9)

Magnetic resonance involves placing a specimen—such as a 90-kilogram (200-pound) porker—inside a device with a strong magnetic field, which causes certain naturally magnetized atoms in the specimen to orient themselves in the field, much as a compass needle lines up with the poles in the Earth's magnetic field.

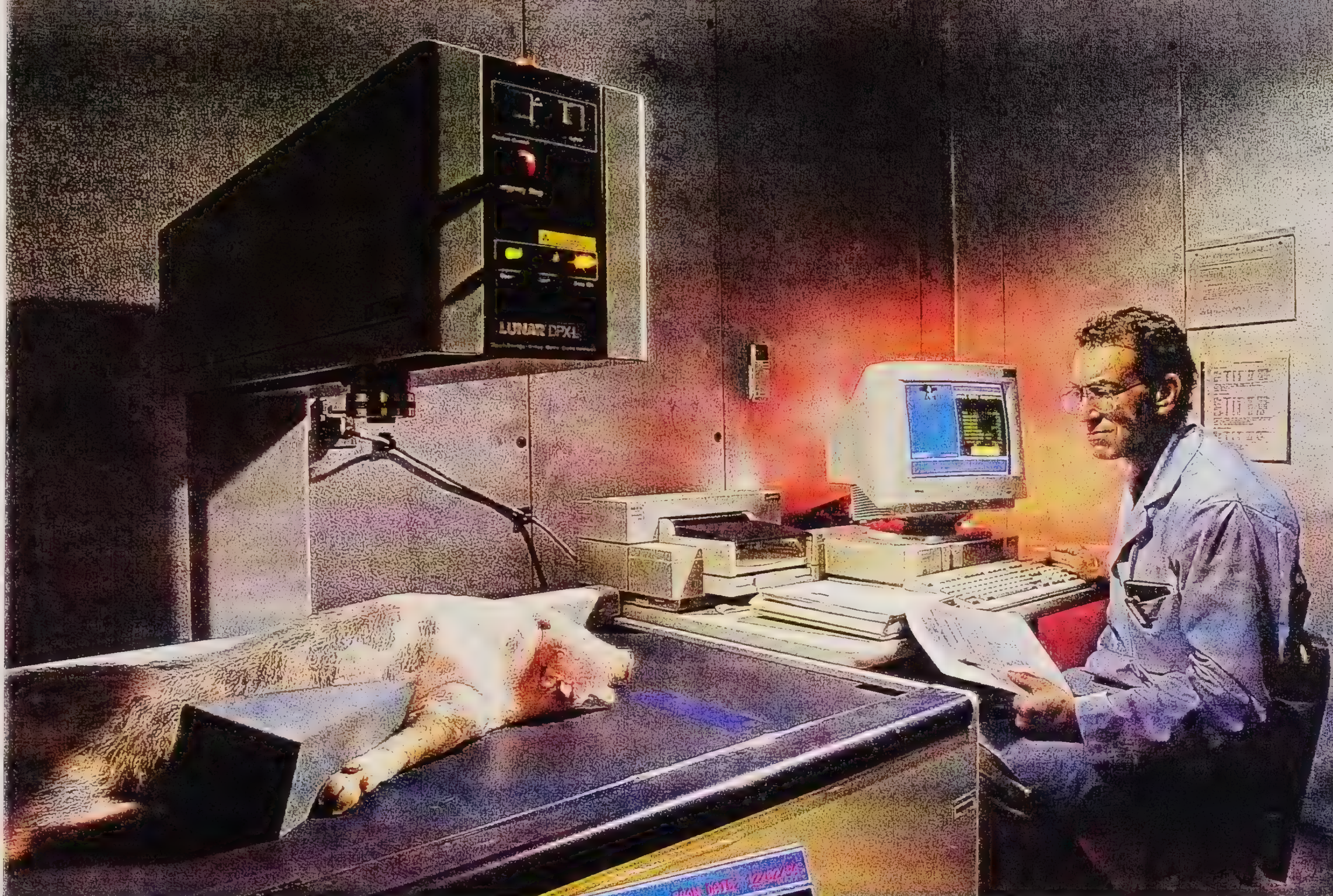
While the atoms are lined up, a short pulse of radio waves is emitted to give them a little push. When that pulse ends, the atoms bounce back into alignment, giving off a faint radio signal that's picked up by the magnetic resonance device. These signals are transmitted to a computer for analysis and converted into a visual image.

"Since this is not a destructive technique, we can follow changes in the animal's body composition as it grows," notes Mitchell.

While the MRI's are as clear as a pork chop on a plate, obtaining them is no picnic. Each pig is anesthetized, then lifted onto the magnetic resonance device's table. Once a pig is in place, a body section up to 40 centimeters long is scanned at increments of one centimeter; then the pig must be repositioned on the table for another scan. At an average of nearly 13 minutes per scan and four scans per pig, a 15-pig day seems interminable.

Mitchell's studies have focused on the impact of diet on pigs, while colleague Armin M. Scholz has used the MRI's to study body type of pigs susceptible to porcine stress syndrome. A visiting scientist from Humboldt University in Berlin, Germany, Scholz says PSS-positive pigs are leaner.

"In my diet study, I scanned 60 pigs, starting at 20 kilograms [about 44 pounds] each, and I followed



KEITH WELLER

KEITH WELLER

Above: Using DEXA, or dual-energy x-ray absorptiometry, ARS animal scientist Al Mitchell can noninvasively measure the body composition of live, anesthetized pigs. (K5908-9)

Left: A DEXA scan of the live pig discloses fat and lean tissue measurements. (K5909-8)

them to 60 kilograms [about 132 pounds]," Mitchell recalls. "I slaughtered animals from each weight group and did chemical analyses of the tissue to determine if the MRI was presenting an accurate picture of fat and lean. There was a good match between the chemical analyses and what I saw on the MRI's."

Mitchell can also check body composition closer to home with a Dual-Energy X-ray Absorptiometry (DEXA) unit next to his Beltsville lab. Unlike the MRI, which presents images of cross-sectional "slices" of the pig's body, the DEXA is a whole-body scan without the distinct internal views.

DEXA uses two different energy levels of X-rays to differentiate between lean and fat, providing percentages and grams of fat and lean tissue throughout the whole body or in a particular area, such as a front or rear leg.

"This system is often used for human body composition studies, but this is the first time it's been used extensively for farm animals," says Mitchell. "DEXA images are not as precise as those in an MRI, but the unit's less expensive and easier to work with technically. Plus, you can get an image of a 90-kilogram pig in 35 minutes.

"These techniques would not be used by the farmer—the equipment is still too expensive," Mitchell says. "But as research tools, they provide a way for us to evaluate an animal without harming it. You don't want to have to slaughter a valuable animal just to see how it's growing."—By **Sandy Miller Hays**, ARS.

Al D. Mitchell is with the USDA-ARS Growth Biology Laboratory, Bldg. 200, Room 205, 10300 Baltimore Ave., Beltsville, MD 20705-2350; phone (301) 504-7124, fax (301) 504-8623. ◆

Bioengineered Tomatoes Taste Great

A tasty new tomato boasts more of the hearty, vine-ripened flavor that's often missing in its supermarket counterparts.

The bioengineered Endless Summer tomato is a result, in part, of work by ARS and University of California at Berkeley researchers. They found, copied, and rebuilt a gene that lets these tomatoes stay on the vine without softening and spoiling. That means the high-tech fruit can develop more of the sugars and acids that make a home-grown tomato taste so sweet and rich.

DNA Plant Technology Corporation (DNAP) of Oakland, California, licensed the gene and used that research, plus the company's proprietary technology, to create Endless Summer tomatoes. Earlier this year, the big, juicy tomatoes were test-marketed in New York.

DNAP business development director Dave Rochlin estimates that they may be on sale in supermarkets throughout the country by 1997.

Typically, supermarket tomatoes have to be harvested while they're green and hard. That's so they won't bruise and rot on the long trip from grower to grocer.

Perhaps most important, they're picked before they can begin to form a natural ripening hormone, ethylene. Once ethylene—a colorless, odorless gas—kicks in, so do all the problems of perishability. Ethylene also triggers natural ripening and spoilage of hundreds of other kinds of fruits and vegetables, like bananas, melons, lettuce, and apples.

In Endless Summer tomatoes, the gene that would ordinarily help the plant make ethylene is retooled, to squelch almost all ethylene production. Because the tomatoes form virtually no ripening gas, there's no need to hurriedly harvest immature fruit.

When exposed to ethylene gas in the warehouse—the procedure used to ripen commercial tomatoes—Endless Summer tomatoes soften, turn red, and stay plump and fresh for about 4 weeks. That's 2 weeks longer than most grocery store tomatoes.

"The longer shelf-life," says DNAP's Rochlin, "means we can ship a consistent supply of these superb tomatoes."

JACK DYKINGA

A retooled gene in Endless Summer tomatoes controls ripening to give better flavor and shelf-life. (K5914-1)

ARS plant physiologist Athanasios Theologis at the ARS/University of California Plant Gene Expression Center, Albany, and co-researcher Takahide Sato isolated and cloned the ripening gene. Normally, the gene cues tomatoes to produce an enzyme called ACC synthase. To make ethylene, plants need that enzyme.

Theologis and Sato did the work in 1989 and applied for a patent. In lab and greenhouse experiments that followed, Theologis and other colleagues blocked 99.5 percent of all ethylene production in about 100 tomatoes by remaking the ACC synthase gene.

His team reported their success in an article that garnered the cover of *Science*, one of the world's leading research journals.

DNAP and two other companies, Calgene, at Davis, California, and Monsanto, in St. Louis, licensed the gene. But DNAP is the first to market a gene-engineered tomato that's derived from the Albany work. The DNAP license permits the gene's use not only in tomatoes, but in about a dozen other produce section favorites as well.

DNAP's bioengineered banana—one that won't turn brown and squishy before you've had a chance to put it on your breakfast cereal—is already in the works.—By **Marcia Wood,** ARS.

Athanasios Theologis is at the USDA-ARS/University of California at Berkeley Plant Gene Expression Center, 800 Buchanan Street, Albany, CA 94710; phone (510) 559-5900, fax (510) 559-5678. ◆

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Mission Statement

The mission of the MU is to reduce the economic impact of animal parasitic and mastitic disease on the safety and health of consumers, and of parasite and mastitis associated production losses to the industry. The goals of the MU are to evaluate the immunobiology of the host response to parasitic and mastitic diseases; protect consumers from zoonotic diseases in food or water caused by parasitic and mastitic diseases; assess cytokines and other immune effector for prevention and control of parasitism and mastitis in farm animals; determine immune and genetic factors that control host disease resistance; identify genes with useful immunologic properties or with effects on parasitic and mastitic disease resistance; define mechanisms through which the parasite or bacterium modifies host physiology and controls pathogen induced stress, and identify, and develop methods to control, parasite and mastitis problems that decrease sustainability of American agriculture.

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Major Research Interests: Development of immunological control strategy for chicken coccidiosis using recombinant vaccine and cytokines. Genetic mapping of chicken genes associated with disease resistance to coccidiosis.

Education and Expertise: National Institutes of Health, National Institute of Allergy & Infectious Diseases, Lab. of Immunology, Staff fellow, Immunology, 1984; Wayne State University, School of Medicine, Dept. of Immunology, Ph. D. Immunology, 1979; Univ. of Connecticut, Dept. of Microbiology, M.S. Microbiology; Univ. of Hartford, Hartford, B. S. 1974, Biology.
*Joined ARS in 1984, has published over 200 peer reviewed manuscripts, abstracts or book chapters. Currently holds three Trust Agreements and two Cooperative Research Agreements with several poultry industries in the areas of coccidia vaccine development and avian mucosal immunity.

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Major Research Interests: Development of vaccine and diagnostic tests for protozoan parasites, including Eimeria of chickens, Cryptosporidium of humans and animals, and Neospora of cattle. The approach common to each research project is to clone and express antigen-encoding genes that may either stimulate protective immunity or be diagnostic for infection.

Education and Expertise: B.S., University of Maryland at College Park, Microbiology, 1979; M.S., UMCP, Microbiology/Chemistry, 1981; Ph.D., UMCP, Microbiology, 1985.
*Joined ARS in 1986, Published Over 25 Papers on Molecular Biology and Immunology of Protozoa. Obtained U.S. and Foreign Patents for Cloned DNA Sequences from Several Protozoa. Developed CRADAs with numerous private companies on developing vaccines and diagnostic antigens for coccidiosis, cryptosporidiosis, and neosporosis.
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Reducing Economic Losses due to Intestinal Parasitic Diseases using Cytokines Naturally Produced by Chicken Lymphocytes

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Background: Arising production problems associated with increasing demands of poultry products require technological intervention to improve quality of poultry products and nutritional needs of the American consumers. One of major problems in poultry production includes coccidiosis, an intestinal infection caused by protozoan parasite, Eimeria, which causes American producers an estimated $600 million annually in medication costs and lost production. Currently, drug therapy is the primary method used to control coccidiosis. However, drugs are expensive and, unfortunately, prophylactic medication is hindered by widespread transferrable drug resistance, and the high costs involved in the development of new drugs. Multidisciplinary approaches to prevent and control coccidiosis and develop genetically coccidia-disease resistant chicken lines are our current efforts.

Research Goals: Specifically, we are trying to: 1) identify cytokines which are naturally produced by chicken lymphocytes which have a detrimental effect on Eimeria parasites, 2). identify immunoregulatory proteins which enhance natural immunity of chickens, 3). identify parasite antigens which can overcome the species-specific immunity and the species variation, and 4). define proper selection markers for genetically determined disease resistance to coccidiosis. The information gained from this research will guide development of integrated parasite control strategies, including the use of vaccines and diagnostic probes and selection of genetically resistant poultry to eliminate, or substantially lessen, disease-induced production losses and disease transmission via the food chain and to lessen their reliance on drugs in an integrated pest management.

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[illegible] eliminate [illegible] subsequently
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DEVELOPING VACCINES AGAINST AVIAN COCCIDIOSIS

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Background: Avian coccidiosis is an intestinal disease of poultry caused by protozoan parasites in the genus Eimeria. Coccidiosis causes an estimated $ 350 million loss per year to the U.S. broiler industry due in part to poor weight gain in chickens infected with the parasite and to the cost of administering anti-coccidial drugs. Although coccidiostats have been useful for controlling the disease, recent appearance of Eimeria strains resistant to coccidial drugs have stimulated efforts to develop alternative methods of combating the parasite. Numerous studies have shown that chickens once infected with Eimeria develop complete immunity to subsequent infection which forms the basis for developing a coccidiosis vaccine.

Goals: The objective of our research is to develop practical and effective vaccines against coccidiosis using either radiation-attenuated Eimeria parasites or specific antigen-genes cloned from the parasite DNA via standard molecular techniques.

Approach: The antigen-encoding genes are inserted into Escherichia coli which produce the recombinant coccidial protein. Chickens are either immunized with recombinant protein or inoculated with radiation-attenuated Eimeria and then challenged with virulent coccidia several weeks later. Weight gain, intestinal lesions, feed conversion ratios are compared between immunized and non-immunized groups

Accomplishments:
- Development of an irradiation protocol for attenuating the 3 major species of Eimeria that results in complete protection against coccidiosis with no clinical effects or release of virulent oocysts.
- Production of recombinant Eimeria antigens in E. coli and elicitation of partial protection against coccidiosis. U.S. patent granted for recombinant genes.

Impact to Industry: The poultry industry is now testing in large-scale field trials irradiated Eimeria as an alternative to anti-coccidial drugs. Several biotechnology companies have licensed the recombinant Eimeria genes for expression in proprietary delivery vectors to develop vaccines against coccidiosis.

Future Research: Immunity against Eimeria is directed against coccidia-infected host cells. Our current emphasis is on identifying antigen-encoding genes expressed by Eimeria parasites metabolizing inside cultured chicken cells. Once identified and cloned, these DNA will also be expressed in E. coli and tested in vaccine trials.

the older version, the new one does not need antibiotics to survive in anaerobic fermentation environments like those of commercial ethanol plants. The scientists are scaling up their laboratory research to the pilot fermentors.

Another recombinant microbe that can ferment both glucose and xylose is a strain of S. *cerevisiae* yeast developed by geneticist Nancy Ho at Purdue. It was also evaluated under an ARS cooperative agreement.

Because this microbial species has long been used to make ethanol, a modified version too might someday work well for the industry, says Bothast. Further research, however, is needed to develop Ho's strain into one that can survive better under industrial conditions, produce ethanol from other sugars such as arabinose, and quickly produce larger volumes of ethanol.

Fungi, Too, Might Join the Effort

In addition to bacteria and yeasts, genetically transformed filamentous fungi could become ethanol plant workhorses.

At NCAUR, microbiologists Christopher D. Skory and Shelby N. Freer envision harnessing industrial and food processing fungi for a "one-pot" method of producing ethanol. The microbes prodigiously spew out enzymes that efficiently break down the corn fiber's cellulose and hemicellulose while producing tiny amounts of ethanol from the resulting sugars. "Through both mutagenesis and genetic engineering, we hope to increase their ethanol production," says Skory.

Similar genetic research could lead to one-pot production of lactic acid that is valuable in food processing and for industrial applications, such as making biodegradable plastics. Developing such a wet-milling coproduct would help offset ethanol production costs, since ethanol is fairly low in economic value.

Considering alternative fermentations of glucose, Freer is screening part of the ARS Culture Collection located at the NCAUR for *Brettanomyces* yeasts that efficiently produce acetic acid from glucose. In earlier screening of the collection, Freer identified a microbe with a gene responsible for producing a beta-glucosidase enzyme that breaks down small cellulose polymers into fermentable sugars. Skory has cloned the gene and inserted it into several other microbes, including ethanol-producing ones.

In still another screening, microbiologist Badal C. Saha has identified a yeast that produces a heat-stable beta-glucosidase that works in environments high in glucose. He is mutating the yeast to try to increase its production of the enzyme so that it can be used to efficiently convert cellulose to sugars.

In addition to trying to get more ethanol from a bushel of corn, the NCAUR researchers hope to increase the usefulness of other ethanol fermentation coproducts.

One abundant low-value product of fermentation is carbon dioxide. NCAUR plant physiologist Brent Tisserat is evaluating the ability of different CO_2 concentrations to speed the growth of plant tissue cultures. He envisions using such cultures one day to produce food flavorings and high-value pharmaceuticals.

At NCAUR, other scientists are researching potential value-added products that can be made from wet-milling coproducts.—By **Ben Hardin,** ARS.

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Two Strategies for Protecting Poultry From Coccidia

If ever organisms lived up to the label "parasite," it is those belonging to the order Coccidia.

Not only do the single-cell protozoans of the *Eimeria* genus infest the nation's poultry flocks, costing American producers an estimated $600 million-plus annually in medication costs and lost production; they also invade and take shelter in the very cells marshaled by the chicken's immune system to defeat them.

Though a vaccine is available in this country against coccidiosis, its key ingredient is a low dose of the live parasite, which stimulates protective immunity. But Hyun S. Lillehoj, who is an immunologist with the ARS Immunology and Disease Resistance Laboratory at Beltsville, Maryland, says the presence of the live parasite may pose problems.

"The live parasite can cause disease in the bird," Lillehoj contends. "If the bird's immune system isn't functioning properly for some reason, the live parasite in the vaccine can overcome the immune system. Also, there can be a negative interaction within the bird with feed contaminants such as mycotoxins or with other infections that might be present, such as salmonella or campylobacter."

Complicating the vaccine situation is the existence of seven different species of *Eimeria*.

"An effective vaccine needs to incorporate elements from all seven species," says Lillehoj. "The vaccine that has the live parasite uses many of the seven strains. But the incidence of variant species of *Eimeria* in the field is increasing, and the live coccidia vaccine cannot protect effectively against all of them. It's also very labor-intensive to produce the live parasites."

Lillehoj favors a different approach. She and her research team—including support scientist Marjorie B. Nichols and technician Melody B. Lowe—have devised a two-pronged strategy to thwart coccidia.

"The chicken's immune system produces cytotoxic T-cells whose function it is to target and destroy infected cells," explains Lillehoj. "That's part of nature's protective immune mechanism against this parasite.

SCOTT BAUER

A flow cytometer used by immunologist Hyun Lillehoj analyzes intestinal lymphocytes that indicate chickens' immune response to coccidia exposure from vaccination or natural infection. (K5130-3)

"But there is a phase of the coccidia life cycle when the parasites are called sporozoites. These actually get inside the cytotoxic cells, which then cannot kill them, but instead deliver the parasites to the part of the intestine called the crypt epithelium, where they exit to develop."

Once nestled in crypt epithelial cells, the thriving coccidia wreak havoc in the intestinal lining and interfere with the chicken's ability to absorb nutrients from the feed it has eaten. Result: The bird doesn't gain weight and may die.

In 1993, Lillehoj and ARS immunologist James M. Trout observed coccidia's commandeering of cytotoxic cells firsthand when they used two fluorescent, color-stained monoclonal antibodies to cling to and track movement of both parasites and cytotoxic cells inside chicken intestines.

Green-stained monoclonal antibodies allowed them to see where the coccidia went; red-stained antibodies pinpointed the presence of the cytotoxic cells. Overlapping red and green colors proved the coccidia invaded the very cells that were supposed to protect the chicken against them.

Part of Lillehoj's plan is to block the initial invasion of those crucial infection-fighting cytotoxic cells by the coccidia.

"The sporozoite has to bind to the cytotoxic cell to get inside it," she explains. "Once it binds, it makes a little dent on the cell. The parasite has a retractable structure called a conoid that makes this dent. Then enzymes from the parasite act on the cell to make an opening for the parasite to get in.

"We've developed and have applied for a patent on a chicken monoclonal antibody that identifies a protein that the sporozoite uses to cling to the cytotoxic cell. In laboratory tests, this antibody actually blocks the sporozoite invasion of the cytotoxic cell."

Lillehoj is working with ARS molecular biologists Mark C. Jenkins and Kang D. Choi on ways to use the protein recognized by the antibody as a potential vaccine. Also promising as potential weapons are cytokines, substances produced naturally by the bird's white blood cells.

We have shown in laboratory tests that some cytokines inhibit development of the parasite," says Lillehoj.

Parasite: "An organism that grows, feeds, and is sheltered on or in a different organism while contributing nothing to the survival of its host," says Webster's New World Dictionary. The word comes from the Greek "parasitos," meaning "one who eats at another's table."

"They also enhance cytotoxic activity by turning precursor cytotoxic cells into active cytotoxic cells. Once activated, these cytotoxic cells kill parasite-infected host cells. Cytokines also activate white blood cells called macrophages to devour the parasites."

Starting in 1995, Lillehoj collaborated with ARS molecular biologist Dante S. Zarlenga and scientists at Korea's Seoul National University to clone the chicken gene that controls manufacture of a cytokine called gamma-interferon. The research team has produced genetically engineered chicken gamma-interferon and is testing its protective powers in live chickens. Early results look promising, Lillehoj says.

"If this works, a bird that's treated with the gamma-interferon might still get infected with coccidia, but it might not lose as much weight or get as bad a case of coccidiosis," she explains. "You wouldn't want to completely block the infection, anyway, because then you wouldn't stimulate the bird's immune system to provide natural immunity against future coccidia infections or other opportunistic pathogens."

Gamma-interferon may prove useful in the battle against coccidia in other ways as well, Lillehoj adds.

"Antigens are proteins from the parasite that stimulate an immune response from an animal's immune system," she points out. "It's been shown in mammalian cells that when you add gamma-interferon to a weak antigen, you get a greater immune response than if you just vaccinate with the antigen alone. Plans are under way to use gamma-interferon as an adjuvant to enhance the action of the vaccine."

Mass production of gamma-interferon may be tricky, Lillehoj says. In lab tests, attempts to reproduce the substance by inserting the gene for its production into fast-multiplying *E. coli* bacteria fell short of the scientists' expectations.

"The protein was not very effective when expressed in *E. coli*," Lillehoj admits. "But once you have a gene that expresses the protein, you can raise it in a mammalian cell line."

One possible solution to the protection dilemma might be to identify an antigen common to all strains of coccidia and use that as the basis for a new vaccine.

"We know of one such segment, but we're not ready to test it yet as a vaccine," says Lillehoj.

The more common game plan—waiting to clean up coccidiosis in flocks after it occurs—is rapidly becoming a risky proposition, according to Lillehoj.

"The major problem is that the parasite develops drug resistance very quickly," she notes. "The main emphasis for control has been on drugs, but the coccidia have developed resistance to all the drugs ever tested against them."

The ARS research team's multifaceted efforts come down to one simple goal: to mimic nature.

"In the field, once birds have been exposed to coccidia, they develop immunity," says Lillehoj. "We've been trying to figure out how chickens get that immunity. Over the years, we've learned a lot about how the parasite invades cells and stimulates natural immunity."—By **Sandy Miller Hays**, ARS.

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KEITH WELLER

Support scientist Marjorie Nichols (right) and technician Melody Lowe examine leghorn chickens of the TK strain for signs of coccidiosis. The one on the right is infected with *Eimeria tenella*, which results in a smaller comb, diarrhea, and weight loss. (K7396-8)

Fire Ants Find Grains Tasty

No one would ever confuse John Morrison with mystery story detectives Sam Spade or Hercule Poirot.

An agricultural engineer by training, Morrison's world is the sun-baked fields of east-central Texas, where he devises workable conservation tillage techniques for clay soils at the ARS Grassland, Soil, and Water Research Laboratory at Temple.

But in the early 1980's, in the midst of a planting study, Morrison unexpectedly joined the ranks of those whose job it is to unravel mysteries—and he uncovered a whole new threat to farmers' economic well-being.

"We had field plots where only 20 to 25 percent of the plants were coming up, so we thought we'd better dig up the seeds and take a look," says Morrison. "Since we were using experimental no-till planters for this area's sticky clay soil, we thought the planters might somehow be damaging the seeds in planting."

Morrison did find damaged seeds in abundance. But the menace wasn't mechanical.

"Fire ants were just invading this area," he notes. "When we dug up the seeds, we found their hearts had been eaten out by fire ants. In some cases, we'd actually find the seed with a fire ant burrowed into it, eating away, with just its tail sticking out."

Accidentally imported from South America half a century ago, the fire ant species *S. invicta* can be found today from Texas to Florida and as far north as Tennessee and Virginia. The ants pose a threat to animals and humans alike. So researchers at the ARS Medical and Veterinary Entomology Research Laboratory at Gainesville, Florida, are pursuing a range of weapons against the biting pests. [See "Fighting the Fire Ant," *Agricultural Research,* January 1994, p. 4.]

Although Morrison first discovered the fire ants ravaging seeds in his no-till cotton field plots, later studies showed that cotton suffered the least from the foraging pests.

Tests at the Temple lab have shown the ants will damage dry wheat seed at a rate of about 11 percent per day—capable of wiping out an entire planting in 10 days' time. Damage on dry corn seed runs about 6 percent, grain sorghum about 7 percent, soybeans about 1 percent, and cotton a mere 0.5 percent per day.

ARS PHOTO (K3637-5)

Fortunately for farmers, a possible deterrent is at hand.

"At about the time we discovered the ants, we were just starting to use liquid starter fertilizer in our no-till furrows at about 100 pounds per acre," Morrison recalls. "When we used that liquid fertilizer, our plants emerged without fire ant damage. That's a 'green' solution, because we'd be putting fertilizer on the soil anyway."

The seed needs protection mostly until germination, according to Morrison. Although fire ants will crunch on tender stems once plants have broken through the soil, their allure is lessened and so is ant damage.

"There's a race between the rate at which the fire ants eat the seed and the rate at which the seeds can take in water, germinate, and emerge from the soil," Morrison says. "In our studies, as the seed gains water and softens, damage from the fire ants is more likely."

Insecticides are also an option for averting the ants. But treating seeds with insecticides can lower their germination rates by 5 to 8 percent, warns Morrison.

Oddly, the liquid fertilizer's effectiveness was significantly less in greenhouse studies in 1994-95. In the greenhouse, it controlled only about 50 percent of fire ants—compared to 80 to 90 percent in the field—so the Temple team plans more field tests. But Morrison says the work has already provided an important warning for farmers in areas with fire ants.

"You have to use either insecticides or other effective repellents to keep these ants from eating your seeds," he notes. "Fertilizer may be one solution, but others may be found in the future."—By **Sandy Miller Hays**, ARS.

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Agricultural Research Service

United States Department of Agriculture

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Mission Statement

The mission of the Meat Science Research Laboratory is to: 1) to conduct basic and applied research on beef, pork, lamb and other animal products to enhance their quality and safety; 2) to develop technology for evaluating, maintaining, and improving the quality of meat and meat products; 3) to establish the nutritional composition of meat and meat products and to establish pre- and post-slaughter practices that enhance both the nutritional composition and quality; and 4) to develop information on the accumulation of residues of drugs and pesticides in meat and other animal products and to develop means for analyzing for such chemical residues.

Research Staff

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Major Research Interests: Develop hydrodynamic pressure technology and other newly emerging technologies that will improve the quality and food safety of meat products. Develop companion preservation, processing and cooking procedures necessary to fully achieve the value-added capabilities of pressure technologies. Regulation of growth and development of different biological slaughter animal for producing high lean/low fat meat, especially in relation to improving meat quality and compositional factors affecting the tenderness of meat.

Education and Expertise: University of Florida, Ph.D. Animal Science, 1983; University of Kentucky, M.S. Animal Science, 1979; University of Connecticut, B.S. Chemistry and Biological Sciences, 1977.
* Joined ARS in May 1983; published over 250 peer reviewed manuscripts, abstracts and book chapters; named University of Maryland - National Capital Area, Gamma Sigma Delta Outstanding Researcher, 1992; named Northeast American Society of Animal Science and American Dairy Science Association Young Scientist, 1991; first place recipient Graduate Student Research Competition, American Meat Science Association, 1984. Currently holds a Cooperative Research and Development Agreement with Hydrodyne, Inc. for developing Hydrodyne technology.

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[illegible] Interests: [illegible] hydrodynamic pressure technology and [illegible] emerging technologies that will improve the quality and food safety of meat [illegible]. Develop [illegible] preservation, processing and cooking procedures necessary to fully achieve the value-added capabilities of pressure technology [illegible] growth and development [illegible] producing high lean low fat [illegible] especially [illegible] improving meat quality and compositional factors affecting the tenderness [illegible]

[illegible] and Expertise: University of [illegible], Ph.D. Animal Science, 1979; University of [illegible], M.S. Animal Science, 1979; University of Connecticut, B.S. Chemistry and Biological Science, 1977.

[illegible] ARS in [illegible] 1982 [illegible] has over 150 peer reviewed [illegible] abstracts [illegible] University of Maryland [illegible] Area [illegible] Consultation Award [illegible] Science [illegible] Dairy Science Association Young Scientist 1981 [illegible] Graduate Student Research Competition American Meat Science [illegible] Cooperative Research and Development [illegible] with Hydrodyne Inc. for developing hydrodyne technology.

TENDERIZING NON-AGED BROILER BREASTS USING THE HYDRODYNE PROCESS

Kimberly I. Meek (Graduate Student-VPI), James R. Claus (Associate Professor-VPI)
and **Morse B. Solomon**
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The broiler industry faces the inability to effectively eliminate or significantly reduce the aging time required during the processing of boneless broiler breast meat. Breast meat must be aged on the carcass for 4 to 7 hours postmortem, which increases labor, refrigeration and storage costs. Additionally, during this extended storage, considerable weight is lost from the breasts due to purge. Early deboning of non-aged breasts (immediately after the initial chill) results in a tough product. The Hydrodyne process, a unique, new technology that utilizes a hydrodynamic shock wave to tenderize meat, may provide processors with the opportunity to eliminate or reduce the aging time. Packaged meat is immersed in water and a small amount of high explosive, suspended in the water, is detonated to create the shock wave. The objectives of this research are to determine the effects of the Hydrodyne process on non-aged breast tenderness compared to that of traditionally aged counterparts and determine the applicability of the Hydrodyne process on improving tenderness of early boned broiler breasts. If tenderness improvements and savings are realized with the Hydrodyne process, increased price competitiveness and consistency in quality will prevail. Hydrodyne treatments resulted in an improvement in tenderness of non-aged breasts. Tenderness improvement resulting from the Hydrodyne treatment was affected by the location/distance of the explosive in the tank and breast location during treatment. Results suggest that the Hydrodyne process may have the commercial potential to eliminate the need for aging breast meat prior to boning.

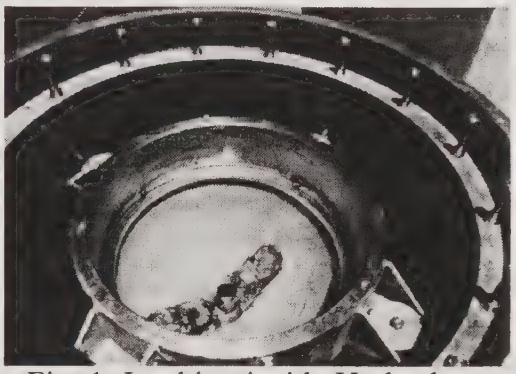

Fig. 1: Looking inside Hydrodyne unit.

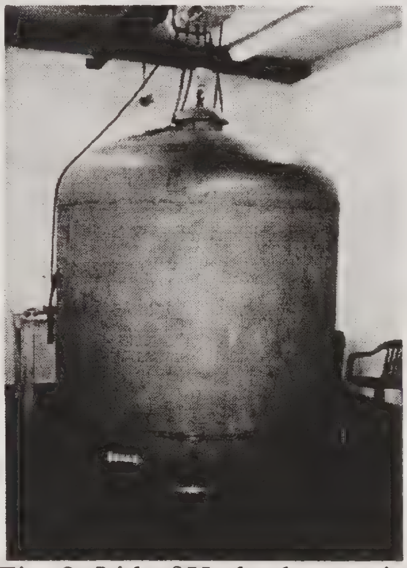

Fig. 2: Lid of Hydrodyne unit.

Agricultural Research Service

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Mission Statement

The mission of the Parasite Biology and Epidemiology Laboratory is to reduce the economic cost of parasitism in livestock and poultry and to reduce the risk of transmission of parasite zoonoses to humans. Emphasis is placed on developing integrated control programs for important parasitic diseases. Research includes basic and applied studies on (1) mechanisms of parasite transmission, the infection process, parasite development and host-parasite interactions; (2) the development of novel methods for parasite control, such as parasite vaccines and non-chemical anti-parasitics; and (3) the diagnosis and control of livestock parasites transmissible to humans.

Research Staff

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Major Research Interests: Control of avian coccidiosis, understanding the nature of the inflammatory response to coccidia infections, defining the unique host responses to the different *Eimeria* species

Education and Expertise: Purdue University, Ph.D., Biochemistry, 1962; Purdue University, M.S., 1959, Biochemistry; Ursinus College, B.S. Chemistry, 1956. *Joined ARS in July, 1967, and has published over 90 peer reviewed manuscripts, abstracts or book chapters.

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Major Research Interests: Mechanisms of cellular invasion by the avian coccidia. Coccidiosis control by chemical and natural products.

Education: University of Maryland, B.S., M.S., Ph.D. (1980): Microbiology, Poultry Science. Involved in coccidiosis research for ~20 years; has published over 180 peer-reviewed manuscripts, abstracts, and book chapters; is co-holder of 6 patents/patent applications. Currently holds five CRADA/Trust agreements with members of industry in the areas of coccidiosis diagnosis and control.

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Major Research Interests: Immunological, chemical and non-chemical control of avian coccidiosis utilizing battery cage, floorpen and field study models. Study of the cellular and molecular development of avian coccidia within host organisms.

Education: Univ. of Georgia, Dept. of Poultry Science, Post-Doctoral Associate, 1975-76; Utah State Univ., Dept. of Biology, Ph.D. Biology, 1975; Utah State Univ., Dept of Zoology, M.S. Zoology, 1972; Univ. of Illinois, B.S. Zoology, 1969.
*Joined ARS in July 1980, has published over 200 peer reviewed manuscripts, book chapters, and abstracts. Currently holds 13 Trust Funds or Cooperative Research Agreements with Vaccine or Pharmaceutical Companies.

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DIETARY MODULATION OF AVIAN COCCIDIOSIS

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Coccidiosis in poultry is caused by protozoan parasites that carry out their reproductive cycles in the host's intestinal tissues, causing economic losses to poultry producers from reduced feed efficiencies, morbitity and mortality. Control of these parasites has generally been through preventative addition of anticoccidial drugs in the feed, the annual cost of which is approximately $100 million. Because coccidia are showing increasing resistance to currently used drugs, new control measures are being sought. Therefore, as part of this effort, we are currently investigating the anticoccidial properties of various natural products, with the ultimate goal of using them as dietary supplements to reduce losses from coccidiosis. To date we have found: 1) supplementation with sources rich in n-3 fatty acids (n3FA) such as menhaden oil and flaxseed oil will reduce infections in the chicken ceca due to *Eimeria tenella*; 2) supplementation with low levels of artemisinin, the natural antimalarial compound from *Artemisia annua*, is effective against *E. tenella* and *E. acervulina* (an upper small intestinal parasite); 3) supplementation with γ-tocopherol from flaxseed and other oil seeds is effective against *E. maxima*, a mid small intestinal parasite; 4) supplementation with the spice, tumeric, which contains curcumin, a medicinal compound also controls *E. maxima*. Anticoccidial feed supplements comprised of naturally occurring substances could be used in conjunction with, and may allow for reduction in use of conventional anticoccidial drugs in large poultry operations, and should be of interest to producers concerned with raising "organically grown" flocks who want to avoid adding anticoccidial drugs to feed. Use of these substances as anticoccidials may increase or open up new markets for existing agricultural commodities. Future research will be concerned with determining how these products work against coccidia infections, in particular, how they affect the functioning of the avian immune system.

[illegible]LATION OF AVIAN COCCIDIOSIS

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Coccidiosis in poultry is caused by protozoan [illegible] that [illegible] represents [illegible] economic losses [illegible] morbidity and mortality. Control of these parasites has [illegible] anticoccidial drugs [illegible] resistance [illegible] currently used drugs [illegible] control [illegible] are being sought. [illegible] we are currently investigating the anticoccidial properties [illegible] with [illegible] supplements [illegible] To date we have found [illegible] supplementation with [illegible] All such as [illegible] oil and [illegible] oil [illegible] infection, [illegible] [illegible] with low levels [illegible] [illegible] supplementation [illegible] effective against E. maxima [illegible] turmeric, which [illegible] supplement compared [illegible] and may allow [illegible] large poultry operations [illegible] Future research [illegible] determining how these products work against coccidia [illegible] the avian immune system.

USE OF A NATURAL PRODUCT, BETAINE, AS A FEED SUPPLEMENT TO CONTROL THE NEGATIVE IMPACT OF COCCIDIOSIS IN CHICKENS

Patricia C. Augustine
Research Microbiologist
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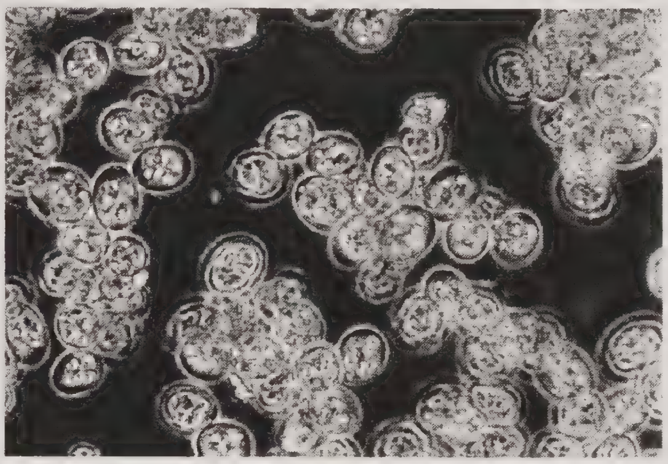

Fig. 1 Oocyts.

Fig. 2: Sugar beets.

Coccidiosis, an ongoing problem to the poultry industry, is controlled in chickens primarily by prophylactic medication from the time of hatch through most of the growout period. Because of drug resistance, the cost of developing and clearing new drugs, and increasing consumer demands for drug-free meat animals, the development of alternative or adjunctive control measures has gained increasing support. Betaine, a product derived from sugar beets, improved body weight, feed conversion efficiency, and intestinal lesions in coccidia-infected chickens when included in feed containing the anticoccidial drug, salinomycin. The effect was not due to direct toxicity of betaine towards the parasite. However, invasion of the intestinal cells by 2 pathogenic species of coccidia, *Eimeria tenella* and *Eimeria acervulina*, was significantly lower in chicks fed diets containing betaine or salinomycin as compared with control chicks. Development of *Eimeria acervulina* was markedly reduced in chicks fed both supplements as compared with chicks fed betaine or salinomycin alone. Electron microscopy revealed that intestinal cells of chicks fed betaine in the diet differed from those of chicks fed diets without betaine. Preliminary evidence suggests that uptake of some nutrients in coccidia infected, betaine-fed chicks was increased compared to that in chicks that were not fed betaine. Collectively, the data indicate that betaine complimented the activity of salinomycin partially through an inhibition of parasite invasion and development and partially to an enhancement of the health of the intestinal cells of the chicks.

[illegible] THE [illegible]
[illegible] IN CHICKENS

Patricia [illegible] Augustine
[illegible]
[illegible]
[illegible]
[illegible]

[illegible] an ongoing problem in [illegible] poultry industry [illegible] by good husbandry [illegible] from [illegible] of the [illegible] development and [illegible] resistance [illegible] drug [illegible] development [illegible] gained [illegible] from [illegible] weight, and conversion [illegible] lesions in [illegible] when [illegible] However, invasion of the [illegible] species of [illegible] significantly lower in [illegible] and diets containing [illegible] salinomycin [illegible]

[illegible]

USE OF VACCINATION IN THE CONTROL OF AVIAN COCCIDIOSIS, A RE-EMERGING DISEASE

Dr. Harry D. Danforth
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A major reason for the impressive production efficiency obtained by the U.S. poultry industry over the past 50 years has been the use of anticoccidial compounds to control coccidiosis, an intestinal disease caused by intracellular protozoan parasites of the genus Eimeria. However, this control is threatened because the parasites have developed an increased resistance to the anticoccidials cleared for use in the poultry industry. Research at the Parasite Biology and Epidemiology Laboratory (PBEL) is directed toward alternative methods of coccidial control by eliciting a protective immune response against the parasites. Two directions of research, some of which are done in collaboration with the poultry, vaccine and pharmaceutical industries, are currently being explored. These are: 1) use of viable and gamma-irradiated oocyst vaccines and recombinant antigens with novel delivery techniques; and 2) use of a combination of viable oocyst vaccines with anticoccidial compounds. Studies on the use of a gel-delivery technique used with modified viable and gamma-irradiated oocyst vaccines developed at PBEL are undergoing expanded field trial evaluation to determine if production parameters in vaccinated birds are equal to or better than anticoccidial treated birds. Floor-pen trials done with anticoccidial-medicated broiler birds, vaccinated with drug resistant strains of coccidia, have demonstrated increased bird performance. Collectively, the results show that incorporation of immunological elicited resistance to avian coccidial infection in the poultry industry would provide an effective control of these economically important parasites.

Betaine, salinomycin and Eimeria

Of the types of *Eimeria* which can effect the broiler, Dr. Augustine has used two of the most common, *E. tenella* and *E. acervulina*, in her studies. Both types of *Eimeria* are associated with intestinal lesions and loss of performance, however *E. tenella* also causes blood to appear in the feces while *E. acervulina* decreases pigmentation.

Dr. Augustine's main interest lies in cellular invasion by *Eimeria*, basically how the parasite gets into the intestinal cell and what triggers further development. She has developed a technique for measuring invasion and subsequent development of *Eimeria* using a monoclonal antibody stain for the refractile body and surface antigens which are found on the parasite.

BETAINE AND SALINOMYCIN RESEARCH

Broilers were fed diets which contained either 0.75 kg or 1.5 kg of betaine per metric ton of feed, in the presence and absence of 66 ppm salinomycin prior to inoculation with *E. tenella* or *E. acervulina*.

At six hours after inoculation, the rate of invasion of these parasites into intestinal cells was decreased in betaine supplemented birds. Broilers given 66 ppm salinomycin and no betaine also registered a decrease in invasion. However, the combination of betaine and salinomycin did not decrease levels of invasion more than either betaine or salinomycin alone.

At two days (48 hours) after inoculation, the generational development of succesful invaders of both types of *Eimeria* were similar regardless of betaine and/or salinomycin treatment.

However, at four days (96 hours) after inoculation, birds fed a combination of betaine and salinomycin had less developmental stages of *E. acervulina* in their intestinal tissue than did broilers fed diets containing either betaine or salinomycin alone. *Eimeria tenella* did not show the same effect to the combination of salinomycin and betaine. In addition, an increase in a non-infective stage of *E. acervulina* was found in the intestinal lumen. Since *E. acervulina* invades the absorptive area of the small intestine, changes in the development and release of this parasite may translate into less damage to the intestinal cell.

(Patricia C. Augustine, Ph.D., USDA-Agricultural Research Service, Livestock and Poultry Science Institute, Parasite Biology and Epidemiology Laboratory, Beltsville, Maryland 20705, U.S.A.)

The prolonged fight:

Poultry Indu

Nutritional mechanisms are becoming more attractive as a method of controlling coccidiosis – an insidious parasitic infection continuously affecting the poultry industry. Recent results have shown that betaine improves the poor performance of coccidia-infected birds.

"In the United States, people are more and more exited about drug-free and organically-grown food animals. It's difficult to control animal diseases without using drugs. But it can be done, and there really is a big push in that direction now. The betaine work is part of this. The natural product may or may not kill the disease organism but will prevent the negative effects of the infection."

stry Versus Coccidia

A microbiologist located in the United States Department of Agriculture's Agricultural Research Service, Dr. **Patricia Augustine** has centered the major part of her work around avian coccidiosis, a disease caused by the *Eimeria* species. Her field of research is huge - *Eimeria* can parasitize a wide variety of bird species, plus the *Eimeria* oocyst can remain viable for years, and is resistant to most disinfectants. In addition, this parasite can be found nearly everywhere poultry are grown.

The cost of developing anticoccidial drugs is high. Although some live vaccines have been used by the poultry industry, none of them have allowed the widespread replacement of anticoccidial drugs in poultry diets. Consequently, the use of nutritional mechanisms to control coccidia is of great interest to the poultry industry. Betaine is being studied by Dr. Augustine in order to determine its effects during coccidiosis. She has found that betaine causes partial inhibition of coccidia invasion and development and may help intestinal cells to maintain their functionality during *Eimeria* infection.

The 7200-acre Beltsville Agricultural Research Center is both a working farm and an experimental one, surrounded by suburban Washington, DC. The center is headquarters of the Agricultural Research Service, the main research agency of the U.S. Department of Agriculture.

BETAINE AIDS INTESTINAL CELLS

Dr. Augustine's results indicate that betaine's effect during coccidiosis may be related to the functioning of the intestinal cell itself, once betaine at levels used in the feed showed no toxicity to the *Eimeria* species. Intestinal cells treated with betaine contain more water even in the presence of *Eimeria*. Water volume is important in the regulation of a cell's metabolic functions and perhaps to its ultimate survival during a period of prolonged stress. Therefore, the effect of betaine on cell water content may help the cell to compensate for stress caused by the parasite.

☐ *Janet Remus*

Fascinating World of Science

Dr. Patricia Augustine is striving towards natural solutions to control coccidiosis, a poultry disease which covers the whole world. Dr. Augustine's targets are practical ones, even though in her laboratory she operates in the main at cellular and molecular levels. She finds it rewarding that her discoveries will help not only the poultry industry but also consumers, all of us.

Dr. Augustine works in a collaborative research and development program together with other scientists and other companies. "Contacts with the business world as well as international ones are very important, especially with coccidiosis. You can progress more quickly when you exchange ideas and carry out collaborative work with other people who are working on the disease."

When Patricia Augustine was thirteen years old, she knew she wanted to be a scientist. And she still considers that one of the best choices in her life was the decision she made some years later to take a job in agriculture, and to study microbiology at college. She is full of enthusiasm as she talks about her job and her interests.

"The world will be better in 2050, and research work holds a key position."

Dr. Augustine actively follows achievements in other areas of science. She finds inspiration in the direction events are presently taking: pollution is being reduced, disease prevention is advancing, and it will even be possible to undo some of Mother Nature's mistakes, for instance it may be possible to prevent some genetic diseases. "I have to admit that I think there are ethical limits. As scientists and as a world population we have to police ourselves. Anyhow, the technologies which will make it possible to make the world better are being developed now. Oh, I would love to be around for the next hundred years and see the developments."

☐ *Marjo Uusikylä*

Agricultural Research Service

United States Department of Agriculture

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Mission Statement

The mission of the Environmental Chemistry Laboratory is to provide solutions to water quality, soil quality and food safety problems associated with the environmental behavior of pesticides, nutrients and trace elements. Current research program areas include the following: 1) development of sustainable agricultural management practices to reduce movement of agrochemicals to groundwater and the Chesapeake Bay watershed; 2) determination of the role of volatilization, atmospheric transport, and redeposition in the environmental dispersion of agrochemicals with emphasis on the Chesapeake Bay; 3) elucidation of processes and mechanisms controlling the environmental fate and transformations of agrochemicals; 4) development of sustainable systems for effective utilization of animal, municipal, and industrial by-products while protecting soil, water and air quality; 5) development of agronomic and genetic methods to reduce levels of cadmium in agricultural commodities to protect export markets; 6) remediation of toxic element contaminated sites using plants or specially designed municipal biosolids; 7) development of analytical methods for detection of agrochemicals and their transformation products in fruits, vegetables and meats; 8) development and application of modern NMR spectroscopy and imaging techniques in agricultural research.

Research Staff

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Major Research Interests: Feathers to fiber: conversion to practice. Identifying the chemical structure of unknown compounds like new insect pheromones and phytochemicals which have important new agricultural and/or biological properties. NMR linking molecular conformation and chemical structure and binding.

Education and Expertise: University of Georgia, Ph.D. Medicinal Chemistry, 1989; University of Wisconsin, M.S. Pharmaceutics, 1985; University of Delaware, B.S. Chemistry 1970.
*Joined ARS, 1989; visiting scientist, Environmental Chemistry Lab 1992; Post-doc Fellow, Nonruminant Animal Nutrition Lab 1989; Author/ co-author of more than 25 peer reviewed manuscripts. Recipient of BARC Technology Transfer Award, June 1996; Certificates of Merit, 1994, 1995, 1996. CRADA with Perdue Farms, 1993-1996. Lead scientist on recently accepted patent entitled "Fiber and Fiber Products from Feathers."

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FIBER AND FIBER PRODUCTS FROM FEATHERS

Walter F. Schmidt
Research Chemist, Environmental Chemistry Laboratory
Natural Resources Institute, ARS, USDA
Beltsville, MD 20705

About 2 billion pounds of feathers are produced annually in the United States. Presently, feathers are converted into a low protein value feather meal, but the production cost for generating feather meal is close to its market sales price. The objective of this research is 1) to reduce the volume of this low value solid by-product and 2) to convert fiber from feathers into value-added commercial products and processes.

6.0 um

Photomicrograph taken by Drs. G. Gassner and B. Wergin

Feathers are not cellulose (the fiber in plants), but keratin (the fiber in wool). Feather fibers however are shorter and much finer than wool fiber. Five ARS employees invented a just recently patented process to make fiber and fiber products from feathers. The wet feathers from the poultry plant are pressed dry, then washed in a polar organic solvent. The wash halts decomposition by removing soluble protein and fats which feed bacteria; the wash is also bacteriostatic. After drying, the quill and fiber are disconnected mechanically, and the fiber fraction collected .

300 um

Photomicrograph taken by Drs. G. Gassner and B. Wergin

Pulp, non-woven, and plastic-like products have been made using this fiber, including writing and filter paper, air filters, adsorbents (including diapers), fabric felt, and clear transparent films. It can be combined with cellulose fibers to make woven fabric, laminates, and excrusions, and with synthetic fibers to make composites as plastic strengtheners, extenders, and fillers. Feathers could be a significant and sustainable commercial source of high quality fiber. Annual fiber sales could equal a half billion dollars.

2.0 um

Photomicrograph taken by Drs. G. Gassner and B. Wergin

Future feather research is to continue optimizing processing for specific commercial end users of the fiber. New specialized high value applications using the fiber are also in process, such as developing formulations for adsorbing specific heavy metals. A concurrent line of research is developing higher value added products made from the quill fraction.

The New York Times

October 13, 1996

Scientist Has Just the Thing for Baby Diapers: Chicken Feathers

By KAREN FREEMAN

One at a time, feathers are certainly light, but they quickly add up to a weighty commodity at a poultry rendering plant, which can process half a million pounds a week. That makes the chicken feathers a prime candidate for new roles, and a scientist at the U.S. Agriculture Department says he has one: cushioning baby bottoms.

The researcher, Dr. Walter F. Schmidt, says he has found a way to turn chicken feathers into low-cost absorbent paper for disposable diapers and other products, like filters.

Paper is made from natural cellulose fibers, from synthetic fibers produced from petroleum or from a mixture of those. Schmidt, a research chemist at the Agricultural Research Service in Beltsville, Md., was preparing feathers for analysis when he noticed that the ground feathers felt similar to cellulose. That prompted him to try making paper.

Chicken-feather diapers are still a considerable distance away from store shelves. The research was partly financed through an agreement with Perdue Farms, the poultry producer based in Salisbury, Md. Perdue has declined to license the technology, so the Agriculture Department will be soliciting bids from other companies to license it.

Willard Phelps, an Agriculture Department official who deals with companies that hope to turn department discoveries into commercial products, said that many poultry companies had expressed interest and that licensees who would create jobs in rural areas would be given preference. The next step will be to bring the laboratory process for making paper up to commercial scale.

Chemically, feathers are very different from cellulose, a long-chain carbohydrate that acts as molecular scaffolding for plants, because they are made of a fibrous protein called keratin, the fiber found in wool, hair and fingernails. But it is the physical properties of fibers, not their chemical properties, that are most important in making paper.

[illegible] are expected [illegible]

[illegible] Dr. Walter E. Scott says he has found [illegible] paper for disposal [illegible] and other products.

[illegible] from [illegible] [illegible]

[illegible] ground teachers [illegible] paper.

[illegible] a remarkable [illegible] women, with [illegible] [illegible] for [illegible] [illegible]

[illegible] partners [illegible]

To be absorbent, fibers need to be straight, not curled or twisted, with plenty of space between the fibers for liquid to flow, and they need a lot of surface area to trap the fluid. Feathers fit the bill, Schmidt said in an interview.

"Feather fibers are straight," he said, "while wool is crinkly, and they have a lot more surface area than wool or synthetics. Under the microscope, they look like fish bones, with big fibers and lots of small fibers perpendicular to the big ones."

The feather fibers also tend to hold on to liquid once they become wet because they are not very compressible. That would mean less chance of leakage when a toddler with a wet diaper climbed into someone's lap.

If feather fibers are so absorbent, how do they keep birds dry? The birds waterproof their feathers by coating them with oily secretions.

Chicken feathers are plentiful, but poultry plants make little profit from their current uses, Schmidt said. Many feathers wind up in supermarkets.

"When you buy a pack of mushrooms and see that brown powder, that's feather meal," he said. The feathers are heated to high temperatures under high pressure, and the resulting powder gives mushrooms a good place to grow. Feather meal is also fed to chickens as a protein supplement.

"But the cost of producing feather meal is high," Schmidt said. "Most of the time, the cost of producing it is about the same as the money made in selling it."

Feather fibers, however, cost less to produce than most of the wood or synthetic fibers used in paper, the Agriculture Department said.

The idea of using waste products to make paper is not new, said Dr. Roy M. Broughton Jr., a professor of textile engineering at Auburn University in Alabama. "You remember rag paper?" he asked. "That kind of paper is still being made, using fibers from the cotton seed that are too short to use for normal textiles."

Researchers are also looking for ways to make paper out of waste fibers from sugar cane, wheat straw and other agricultural residues, Broughton said. And a plant called kenaf, which is similar to jute, is being grown for its fiber in Asian and Pacific nations that have a shortage of wood as a source for paper.

Feather fibers, however, offer high absorbency at a relatively low cost. "Feathers are pretty good at soaking up water," Broughton said, explaining that they will hold several times as much water as ordinary paper.

Feather fibers also seem to be a good candidate for a source of industrial filters, like those used in air filters for trucks and tractors, said Marshall Hutten, manager of filtration media technology for Hollingsworth & Vose, a filter manufacturer in Hawkinsville, Ga. He has experimented with the fibers at the

Institute for Paper Science and Technology, which is affiliated with the Georgia Institute of Technology.

"We always need better raw materials for filters," he said, "and some companies that make filters are taking a look at it. But the work is at a very early stage."

It is fairly easy to make absorbent paper from feathers, Dr. Schmidt said, and insoluble proteins like the keratin in feathers rarely cause allergies. The feathers are even the right color -- commercial chicken strains are white -- so they need no bleaching.

Color was the factor that kept an earlier biological candidate for disposable diapers, peat moss, off the market, Schmidt said. "You can't turn peat moss from black to white," he explained, "and no one wants black diapers."

Burger King had a Big Order

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Agricultural Research Service

United States Department of Agriculture

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Mission Statement

The mission of the Instrumentation and Sensing Laboratory is to develop new and innovative instruments and sensors that are useful to agriculture, by applying state-of-the-art technologies of electronics, optics, computer, pattern recognition, and artificial intelligence. The laboratory conducts basic research to characterize the physical, chemical, sensory, nutritional, and aesthetic properties of raw commodities. The laboratory devises nondestructive, non-invasive, and rapid systems to measure those attributes that comprise the postharvest quality of commodities.

Research Staff

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Major Research Interests: Automated inspection and grading of poultry and meat, nondestructive sensing techniques for quality and safety of agricultural products

Education and Experience: University of Rochester, Ph.D. Mechanical and Aerospace Science, 191970; University of Rochester, M.S. Mechanical and Aerospace Science, 1966; National Taiwan University, B.S. Mechanical Engineering, 1962.
*Joined ARS in 1973. From 1986 to 1990, he was Research Leader of the Biological Engineering Research Unit, Roman Hruska U.S. Meat Animal Research Center, Clay Center, Nebraska. In 1990, moved to Beltsville, Maryland as Research Leader of the Instrumentation and Sensing Laboratory; has authored and co-authored over 150 publications; on the Editorial Advisory Board of Computers and Electronics in Agriculture and the Editorial Board of Bioresource Technology; currently holds a Trust Agreement with a foreign research institute and two Cooperative Research Agreements with U.S. private companies.

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AUTOMATED SYSTEM FOR ON-LINE POULTRY CARCASS INSPECTION

Yud-Ren Chen
Research Leader
Instrumentation and Sensing Laboratory
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An automated on-line poultry inspection system is needed for slaughter plants to meet the on-line, bird-by-bird inspection required by the federal government at ever-increasing poultry processing line speed. It would increase the slaughter plant productivity and improve the federal poultry inspection program. The Instrumentation and Sensing Laboratory (ISL) has been applying visible/near-infrared (Vis/NIR) spectrophotometry and multi-spectral imaging techniques to develop an accurate, reliable, and low cost machine vision system for inspecting poultry carcasses on-line at slaughter plants.

Our research showed that when sensing carcasses in an environment without room light using the Vis/NIR spectrophotometer system, wholesome and unwholesome (septicemic, cadaver, bruised, and air-sacculitic) carcasses could be classified with 100% accuracy. When sensing in room light, the best model had an accuracy of 96.2% at a shackle speed of 60 birds/min and 96.8% at a shackle speed of 90 birds/min. With the multi-spectral imaging technique, it could also effectively separate the septicemic and cadaver birds from the wholesome ones with over 93% accuracy, and it could separate tumorous birds from the wholesome birds with minimum error.

A pilot-scale machine vision system for studying poultry carcass inspection process automation in the laboratory was completed and tested.

An ISL industrial prototype system for on-line automated poultry carcass inspection was also assembled and is ready for slaughter plant testing. The industrial prototype system consists of four black/white cameras and a Vis/NIR spectrophotometer. The ISL system images the exterior of each bird with spectral cameras and probes bird's tissues with a Vis/NIR spectrophotometer. Four black/white cameras are equipped with two different optical filters. These four cameras are used to image the front and the back of the birds on the moving shackle at the processing line speed. Optical sensors are used to trigger the capture of the spectral images and the Vis/NIR spectral signals. It also identifies empty shackles. The ISL automated machine vision poultry inspection system is very accurate in differentiating wholesome from unwholesome birds.

Update

Robotic System Inspects Chickens Instantly, Sorts Bad From Good

CONTACT: Dr. Yud-Ren Chen, Research Leader, Instrumentation and Sensing Laboratory, Agricultural Research Service, USDA, Beltsville, MD, (301) 504-8450.

A research engineer is building a robotic light-sensing system that can instantly spot wholesome chickens on a processing line. Birds with possible defects and signs of diseases would be sent to a reject line for closer examination.

Dr. Yud-Ren Chen of the U.S. Department of Agriculture says the system—now being used for trial runs in several East Coast chicken processing plants—"sees" defects such as improperly bled chickens and diseases like blood poisoning. "It sorts out healthy chickens from those that are possibly sick, but it does not identify those with contamination from *E. coli* bacteria or other food-poisoning bacteria," Chen says.

"Chickens with blood poisoning (septicemia) and those improperly bled account for over half of the carcasses currently removed from the processing lines by inspectors," says Chen, who heads the agency's Instrumentation and Sensing Laboratory at the Beltsville, Maryland, Agricultural Research Center.

Using robotics to identify healthy birds, he says, would reduce the number for manual inspections, allowing inspectors more time to monitor for bacterial contamination. Other technologies to detect bacteria are still under development; inspection is now done by "sight, touch, and smell," Chen says.

Chen describes the way the system, technically known as automated instrument inspection, would work: "As chickens roll down the processing line—up to 90-per-minute—a robotic arm positions a spectral camera for a near-infrared image of each carcass and places a fiber optic probe to scan each chicken's breast.

"Instantly, by sensing differences in light reflected from the carcasses, a computer decides if a chicken has signs of defects or disease. The unwholesome birds are redirected to a reject line for closer examination," he says.

Chen notes that during the past four years his laboratory has developed prototypes for the entire system except for the robotic arm, which can be readily adapted by private industry from commercially available technology.

The prototypes include the camera and the optical probe, which has an average accuracy rate of over 95 percent. "To maintain that accuracy, it needs retraining occasionally to adjust to different chicken breeds or chickens fed different rations, for example. In the next three years, we expect to have that accuracy rate improved and made applicable to a broader range of conditions and symptoms," he says.

-more-

CONTACT: Dr. Yud-Ren Chen, Research Leader, [illegible] Laboratory, Agricultural Research Service, USDA, Beltsville, MD. (301) 504-8450

A research engineer is building a [illegible] system [illegible] [illegible] possible [illegible] [illegible] closer examination.

[illegible]

[illegible] bacteria," Chen says.

[illegible] inspectors," says Chen, [illegible] Laboratory in Beltsville, Md., of the Agricultural Research Service.

[illegible]

During that same time period, Chen hopes to combine the camera and the probe to identify just about all of the problems inspectors are looking for, except bacterial contamination. "The package should be ready for commercial use within the next few years," Chen adds.

He says the increasing popularity of poultry products has made the change to instrument inspection even more important. "The number of chickens slaughtered at federally inspected plants annually is 7 billion, compared to 2.8 billion in 1965. If you are going to increase the accuracy of meat and poultry inspection, you have to use machine vision and other automated sensors," he says.

The probe assembly and power pack occupy three shelves of a small rolling cart that resembles a portable TV table.

The probe bounces light off each carcass and the returning light is analyzed by a spectrophotometer and computer. Chen says the computer recognizes septicemia and improperly bled chickens by the differences in reflected light caused by differing degrees of skin color as well as differences in invisible near-infrared light caused by differences in body composition.

The spectral camera, which Chen is adapting for use in the humid environment of poultry plants, creates visible and near-infrared images of each carcass that can be analyzed by a computer to identify diseased carcasses and determine whether the chicken is abnormally small or defective in any other way, he says.

Dr. Pat Basu, director of the technology transfer and coordination staff for USDA's Food Safety and Inspection Service, said that machine vision is "a tool that will definitely aid in automating and modernizing our inspection system. With the new proposed poultry enhancement program just published by our agency for comment, the industry may have to assume the role of separating the wholesome from the unwholesome product before the USDA inspector inspects the bird. In which case, the industry may benefit by having a system that accurately identifies the pathology and defects rather than training personnel to perform these tasks."

Basu adds, "Because of developments by Dr. Chen and private companies, I am sure that the dream of machine vision sorting the bad from the good on the processing line will be a reality within the next few years."

October 1994 —By Don Comis, ARS-USDA, (301) 344-2748

NOTE TO EDITORS: Color slides are available from Anita Daniels (301) 344-2956.

Agricultural Research Service

United States Department of Agriculture

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Mission Statement

The Insect Chemical Ecology Laboratory is part of the United States Department of Agriculture, Agricultural Research Service, Plant Sciences Institute. It serves the people of the United States of America directly and indirectly by supporting pest management programs of State and Federal action agencies. It is an organization dedicated to discovery and development of new, effective, and environmentally benevolent chemicals for the management of beneficial and pest insects by behavioral manipulation. Chemists and entomologists within the Laboratory conduct interdisciplinary research on natural-chemical aspects of behavioral interactions between insects and their environment. Synthetic compounds that influence insect behavior are also discovered and developed. The research is conducted using the highest scientific and ethical standards and employing state-of-the-art entomological and chemical methods. The Laboratory is committed to improvement and maintenance of the environmental health of the nation.

Research Staff

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Albert B. DeMilo (Project Leader)
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Major Research Interests: Conducts research on discovery, synthesis, and development of insect attractants (mostly fruit flies) for use in detection programs, population surveys, and integrated pest management schemes for their control. Also, conducts research on the discovery, synthesis and development of insect repellents for use by the Department of Defense as personal protectants against disease carrying insects.

Education and Expertise: University of Maryland, M.S., 1965; Hofstra University, B.S. Chemistry, 1957.
*Joined ARS 1963, published over 120 publications and abstracts. Recipient BARC Technology Transfer Award, June 1996. Recipient ARS funded Postdoc 1993. Co-recipient of California Citrus Board Research Grant on development of fruit fly traps and dispensing systems 1995, and co-recipient of two Area-Wide Pest Management Grants (1995, 1996) on development of new corn rootworm attractants.

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Major Research Interests. Conducting research in [illegible] [illegible] [illegible] and [illegible] of insect attractants, namely [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] surveys, and integrated pest management [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] compounds research in [illegible] discovery, synthesis, and development of insect [illegible] for use by the Department of Defense [illegible] personal protection against disease [illegible] insects.

Education and Employment: University of Maryland, M.S., 1983; [illegible] [illegible] University, B.S. Chemistry, 19[illegible]7.
[illegible] [illegible] ARS 1983, published over 120 publications and abstracts. Recipient [illegible] R&D Technology Transfer Award, [illegible] 1986. [illegible] Award [illegible] 1993.
Co-[illegible] of [illegible] [illegible] Citrus Board Research Grant on [illegible] development of [illegible] [illegible] traps and dispensers [illegible] 1995 and co-recipient of [illegible] [illegible] Pest Management [illegible] 1995. [illegible] on development of [illegible] [illegible] [illegible] [illegible]

FRUIT FLY ATTRACTANTS FROM PROCESSED CHICKEN FEATHERS

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The West Indian fruit fly inhabits regions ranging from Mexico to Brazil and is a serious pest of mangos, guavas, and other commercial crops. Food bait attractants such as borax-buffered 10% NuLure or 2.2% torula yeast are currently used in McPhail trap deployment to detect, monitor and control populations of the West Indian and Mexican fruit fly. Despite widespread use of these lures, research continues to develop better ones. Plants and animals have long been fertile areas to investigate for new leads to insect attractants. Various degradative techniques (i.e., hydrolytic, enzymatic, fermentations) of these protein-containing sources have been successful in yielding efficacious lures, NuLure and torula yeast being among them.

The need to develop new uses to consume chicken feather waste coupled with the fact that a mixture of chicken feather hydrolysate and soybean paste was attractive to the Japanese orange fly led us to investigate chicken feathers as a source of proteins that could be chemically converted (i.e., hydrolyzed) to a liquid that could function as an attractant for not only the West Indian fruit fly but the Mexican fruit fly as well. Thus, a chicken feather hydrolysate was prepared by heating pulverized feathers with 6 normal hydrochloric acid for 4 hrs at 65°C. The hydrolysate was tested for attractancy at various pH's against the West Indian and Mexican fruit fly. In cage-top laboratory tests to determine the influence of pH on attraction, the hydrolysate, adjusted to a pH 8.0, elicited the greatest response from adult West Indian fruit flies; the attraction response was more than twice that observed for a 10% NuLure standard. Neutral or slightly acidic preparations of the hydrolysate were less effective. While the Mexican fruit fly was less attracted in laboratory tests to a 25% concentration of the hydrolysate than a 10% NuLure standard, the West Indian fruit fly appeared slightly more attracted to the hydrolysate than to NuLure. In a 5-day field test using sterile released Mexican fruit flies, 4.5% chicken feather hydrolysate, adjusted to pH 8.0, caught almost 2.5 times more flies than 10% NuLure. Twenty-three volatile compounds that emanated from chicken feather hydrolysate were identified by headspace analysis using GC-MS and GC retention index comparison techniques. Among the volatiles were 7 ketones, 6 alcohols, 2 aldehydes, 2 chlorocarbons and 2 furans. At pH 8.0, the five most abundant compounds in decreasing order were 4-methyl-2-pentanone (76.3%), 4-methyl-2-pentanol (16.5%), 1-hexanol (3.1%), 1-heptanol (0.81%) and 2-butoxyethanol (0.64%).

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Support for US poultry research lags behind livestock commodities

"All animals are equal but some animals are more equal than others" Old Major, the prize Middle White Boar, from Animal Farm

Feedstuffs August 26, 1996, Volume 68, Number 36
S. L. Pardue

George Orwell's 1945 classic satire on Stalinist Russia and communism, Animal Farm, may appear far removed from U.S. ag policy, yet at least one possible parallel may be drawn: "All ag research is important but some is more important than others". Within the past three decades, dramatic shifts have occurred in the allocation of public resources for swine, dairy, beef and poultry research. The redistribution of these resources, personnel and funding for basic and applied research, toward swine in particular have occurred at the expense of poultry.

Scientist Years
In 1966, the number of "scientist years" (SY) funded for beef, dairy, poultry, and swine were 540, 595.7, 477.6, and 232.7, respectively (FIGURE 1). Approximately, 30 years later, the combined number of SY in these four commodity areas have declined by 16%. However, changes in SY vary greatly among these commodities. Dairy and poultry have received greater relative reductions with losses of 33 and 31%, respectively. Beef associated SY have remained virtually unchanged (-2%), while positions in swine have actually increased by 24% (FIGURE 2). The decline in the number of research projects (RP) in these commodity areas also follows a similar pattern (FIGURES 3 & 4). Once again, poultry (-59%) and dairy (-43%) have seen the largest percentage decreases. The loss of RP for beef (-23%) and swine (-9%) have been more modest. The reductions in dairy allocations can be more easily justified than those received by poultry given changes in production, consumption, and total commodity value. Support for this opinion is described in subsequent sections.

Funding Ag Research
Research allocations, including overhead, from the Cooperative States Research Service (CSRS, now CSREES) for the four major animal-based commodities are shown in FIGURE 5. In 1966, beef, dairy, poultry, and swine were allocated approximately $14.1, $13.9, $10.3, and $6.5 million from CSRS. At that time, dairy, poultry, and swine research received 99, 73.5, and 46.1% of the funding allocated for beef research. In 1994, CSRS allocations for dairy, poultry, and swine represented 84, 63.1, and 66.9% of beef funds. Obviously, changes in the overall rate of growth for these research funds are significantly different for these four areas (FIGURE 6).

Total research funds (USDA research funding, other federal agencies, and state appropriations) including overhead, are displayed in FIGURE 7. In 1966, dairy, poultry, and swine were allocated research funds that were equivalent to 100.6, 77.0, and 45.3% that of beef. Today, funding for dairy research represents 75.8% of the allocation provided for beef. Similarly, funds for poultry research have received a relative reduction and represent less than half the allocation provided for beef ($185.8 vs. $92.1 million). This is not to suggest that ag research funding has declined, on the contrary it has expanded. The point to make is however, that the relative rates of increase within these four commodities has been vastly different (*i.e.* a 638% increase for swine vs. a 316% increase for poultry) (FIGURE 8).

Production and Consumption Trends
These apparent inequities are compounded when one examines them in the context of global, national, and state trends of poultry production and consumption. From 1970-1995, global poultry production rose an astonishing 240%, a rate approximately 8 times that of beef and almost double that of swine (FIGURE 9). During the same period, US per capita poultry consumption increased by approximately 100%, while beef and pork consumption fell by 15 and 7%, respectively (FIGURE 10). Declines in dairy consumption are

misleading. They primarily reflect the reduction in fluid milk consumption, particularly whole milk. Consumption of dairy products, *i.e.* cheese, have risen significantly. Poultry (98.1 lbs) consumption (carcass weight basis) in the US now exceeds that of beef (96.8 lbs) and pork (67.3 lbs) (FIGURE 11). On a boneless weight consumption basis, poultry and beef are essentially equal and pork consumption is approximately 23% below that of poultry.

Do Funding Inequities Exist?

I am not suggesting that a grand conspiracy has been formulated by state and federal ag policy makers to deprive poultry of its fair share of scientists and research funding. But something has happened in the past 30 years that has disproportionally reduced public resources for poultry research. In 1966 there were approximately 88 SY provided in poultry for every 100 in beef. By 1994, only 62 poultry SY existed for ever 100 in beef. During the same period, poultry research funding has dropped from $77 per $100 allocated for beef to only $50. What makes these trends even more puzzling is the fact that they occurred while US poultry production and consumption were exploding. The apparent de-emphasis of poultry research in national and state agricultural policy may have its roots in priorities and attitudes of more than 100 years ago. In a report to the Board of the New York Agricultural Experiment Station, Director Peter Collier wrote these words in 1889, "*It is not a little strange that in the establishment of agricultural experiment stations, the poultry industry should have been so utterly ignored. Were it an unimportant branch of agriculture, were the value of poultry products comparatively small, it would be different, but as everyone knows their value stands second to scarcely any product on the farm...*". To some degree, Collier's statement could have been made in 1996 as easily as it was in 1889.

Possible Reasons for the Differing Allocation of Resources for Commodity Associated Research

Historical Societal Attitudes

While I will readily admit that historical perceptions of poultry are not major factors that have led to the relative decline of publicly funded research for poultry, they may contribute to such an effect. Early images of poultry frequently focus on the farm housewife holding cracked corn in her apron and scattering it to her barnyard flock. The chickens were "women's work". The chicken flock was viewed as less significant. The term "chicken feed" to describe something cheap evolved out of this concept of limited value. The cowboy astride his horse watching over a herd of longhorn cattle certainly conjures up more powerful images. Ironically, it was "butter and egg" money that kept many a farm solvent during the Depression. Clearly the individual value of a chicken was and remains far less than that of cattle or swine. The difficulty arises when, for example, the *aggregate* value of 7.34 billion broilers is not fully appreciated.

"Cows and Pigs are Bigger"

Because cattle and swine are larger animals, it might be suggested that additional resources are needed to cover the increased costs of conducting research with these species. Other arguments concerning the greater length of time required to study a trait in swine or cattle and the associated increase in costs have been made. There is some degree of validity to these points. However, the cost and time differential between large animal research and poultry is not as great as it would appear. Layer and breeder studies can require up to two or more years to complete. In addition, poultry research may utilizes hundreds or thousands of birds, while many studies in cattle or swine may have only a few dozen animals in the study.

Political Forces

Former Speaker of the House, Tip O'Neil once stated that all politics were local. Mobilizing grassroots political forces for some commodities would appear to be easier than for others. With a concentration into larger production units, fewer individual farms and ranches have poultry on-site. For example, in 1994, a total of 4,318 North Carolina farmers contracted with poultry integrators to produced poultry meat and eggs. Contrast those numbers with the 32,000 North Carolina farmers who have beef cattle. Although the value of beef production in North Carolina is only 9% that of poultry, the number of farms and potential voters outnumbers poultry by almost a 7.5 to 1 margin. Because beef cattle production occurs in the majority of legislative and congressional districts, organizations such as the Cattlemen's Association have a pool of constituents throughout the country. These organizations can effectively influence resource allocations, particularly at the state level.

Another factor in local and state politics is the growing adversarial relationship between some contract growers and poultry integrators. Swine and cattle producers, even those with a few head, tend to be advocates for research related to their commodity. Complaints from growers that publicly-funded poultry research only benefits the large integrator has a chilling effect on grassroots support for this commodity. The accuracy of the complaint is debatable; however, attitudes such as these create an environment that does not serve the broader interests of poultry very well.

Vertical Integration & Consolidation

US poultry meat production occurs almost exclusively in vertically integrated (VI) companies. A system such as VI allows one company to manage all phases of production, and by doing so, enhances efficiency and lowers costs. With VI, the poultry industry has seen a consolidation of production into fewer, but larger companies. Today the top 20 broiler companies control approximately 80% of the market. Some have argued that these large agri-businesses do not need publicly-funded research and that other commodities should receive preferential funding, an event which I claim has already occurred. If the size of these companies has somehow reduced their need for publicly-funded research, why is the same not true for other commodities? For example IBP, which exclusively processes beef, had sales in 1995 of approximately $12.7 billion dollars. The most visible poultry processor, Tyson Foods had sales of $5.5 billion, less than one half of those generated by IBP. In addition, swine production has seen a rapid increase in VI in the past decade and relative increases in research funding for this commodity have occurred at a rate two times that of poultry.

While VI firms frequently have PhDs and DVMs on their staffs, the vast majority of "basic" ag research occurs in the public not the private sector. Privately funded corporate research routinely focuses on "applied " research which is conducted to find solutions to immediate problems. Whether the end user of research is a large VI company or a small producer, the need for that research is the same. From a simplistic perspective, the chicken does not know if it is raised in a VI or independent grower environment. Another point of concern is where will the poultry nutritionists, geneticists and physiologists of the future be trained if the relative support for poultry research continues to decline.

Commodity Value

In 1995, the value of the US beef industry was approximately $34.0 billion (FIGURE 12). By comparison, dairy, poultry, and swine were valued at approximately $19.5, $18.6, and $10.1 billion, respectively. One argument can be made that because beef generates roughly 45% more value than poultry, that it should receive a greater proportion of research funding. Up to this point I have no disagreement. The "total value" argument breaks down when allocations for poultry are compared to either dairy or swine. Based upon the total value concept, poultry and beef have received a disproportionately lower amount of funding. If 1994 total funding was based solely on commodity value, beef research would receive approximately $213 million (vs. $186), dairy would be reduced to $122 million (vs. $141), poultry would receive an increase to $116 million (vs. $92), and swine have a reduction to $63 million (vs. $96), respectively. Based on these assumptions, dairy is over funded by a modest 16%, while swine has received excess funding in the amount of 52%. If SY were also allocated strictly on a commodity value basis, beef would receive an additional 111 SY and poultry an additional 20 positions. In contrast, dairy would lose 32 positions and SY devoted to swine would be cut by 99, a 34% reduction! As was observed with research funding, allocation of SY for both dairy and swine exceed their relative market value.

Regionalization

Following the second World War poultry production, and in particular broiler production, became concentrated in the Southeast. Today greater than 85% of broilers are produced in the southeastern quadrant of the U.S. As production became regionalized, many states outside this region witnessed a decline in their local poultry industry. Reflecting these changes at the state level has been the demise of Poultry Science departments at land-grant universities. In 1960, there were 44 Poultry Science departments; today there are less than 12. In contrast to the approximately 75% reduction in Poultry Science departments since 1960, there has been a 190% increase in poultry consumption. Since resources are allocated by-in-large at the state Experiment Station level, the downsizing of the poultry industry within a state inevitably leads to a reduction of funding. As the number of Poultry Science departments declined nationally, in response impart to regionalization, merger into Animal Science departments was typical. Because Animal Science department heads and directors of

Experiment Stations would be aware of declining public support for poultry in these states, poultry positions were in time filled by swine and ruminant affiliated scientists. I agree that this is prudent policy. Economic forces should alter an institution's mission and by doing so influence the allocation of its resources. Having said that, let me focus on what, in my opinion, has been the primary basis for the relative loss in public funding of poultry research.

The Commodity Income: Research Allocation Paradox
The reallocation of Experiment Station positions and funding for poultry, in those states with a limited poultry presence, is understandable. It is the absence of significantly greater resources and positions in states which have had a rapidly growing poultry industry for decades, that I believe has contributed most to the de-emphasis of poultry research on a national basis. Poultry production in a number of eastern and southeastern states has doubled or tripled in the past decade alone. Yet in some of these states, the allocation of resources and personnel for poultry have remained stagnant or have even declined. One could question why the number of positions and research funding for poultry does not more accurate reflect the relative economic importance of this commodity in many southeastern states. For example, three such states, which are each ranked in the top five nationally in poultry production, had a combined research expenditure for poultry of $10.1 million in 1994. In each state poultry was the number one agricultural commodity, ranging from approximately 30 to 57% of cash receipts from farming. In these same states, almost $15 million was expended for beef and dairy research. In one state, poultry generated approximately five times the income from beef and dairy combined, yet poultry received 36% less research funds.

In their defense, Experiment Station directors frequently inherit programs and personnel from previous administrations which effectively limits their ability to make rapid programmatic shifts. University-based organizations tend to change by evolution rather than by revolution. The pre-existence of popular, although economically insignificant programs, the presence of tenured research faculty, and local and state political realities all impede the ability to scale-up or downsize a program. Adjustments in program emphasis require long-range planning and the ability to "hit an ever moving target". As has been the case in swine, small steady gains over a number of years results in substantial reallocation of resources.

Conclusions
Publicly-funded ag research is essential for any commodity. The equitable distribution of those funds is challenging. The ability of state Experiment Stations to function with a high degree of autonomy provides an opportunity for decision making to be based on state needs and not some poorly defined federal mandate. Current national funding trends suggest that some commodities (*i.e.* swine and dairy) may have received resources at a rate which does not accurately reflect their value. It also appears that poultry and beef research are relatively under-funded. On the whole, beef has faired far better than poultry over the past 30 years. Obviously, commodity value should not be the sole criteria in the allocation of research funding. However, each state must examine its own commodity funding in light of the economic impact that is associated with that commodity, now and in the future. It is not an easy task.

Finally, the record of scientific achievement demonstrates that public resources allocated for poultry research have been well spent. Few, if any, commodities have seen the level of improvements in growth rate, feed efficiency, and reproductive performance (*i.e.* table eggs production) that have occurred in poultry. These advances are directly associated with the information generated from poultry-related research. As U.S. taxpayers demand greater and greater accountability, poultry research has already established a quantifiable record of maintaining the public trust. Investment in poultry research has paid dividends not only for the producer and processor, but the consumer as well. Additional resources will stimulate even greater achievement.

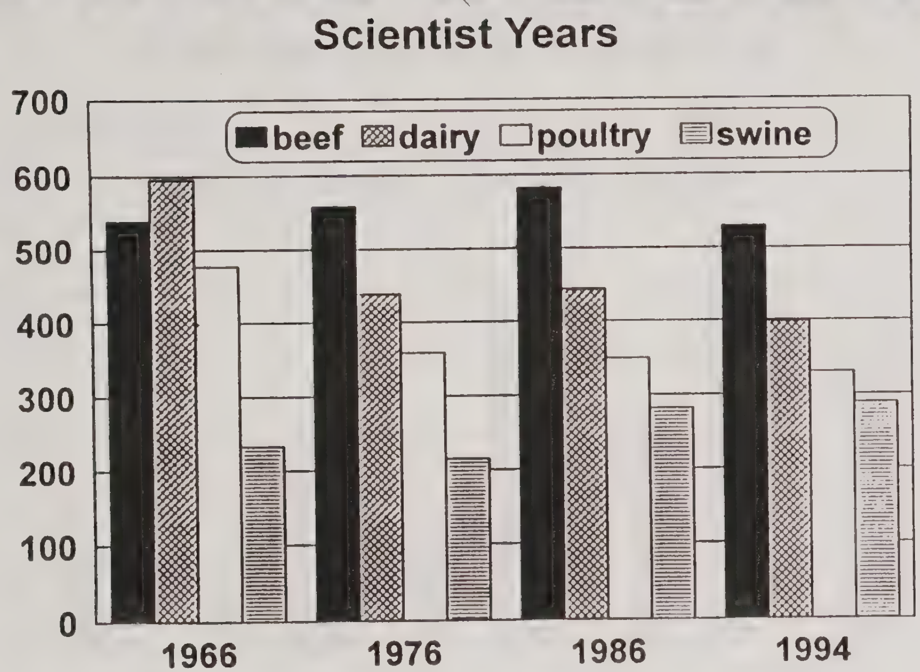


FIGURE 1

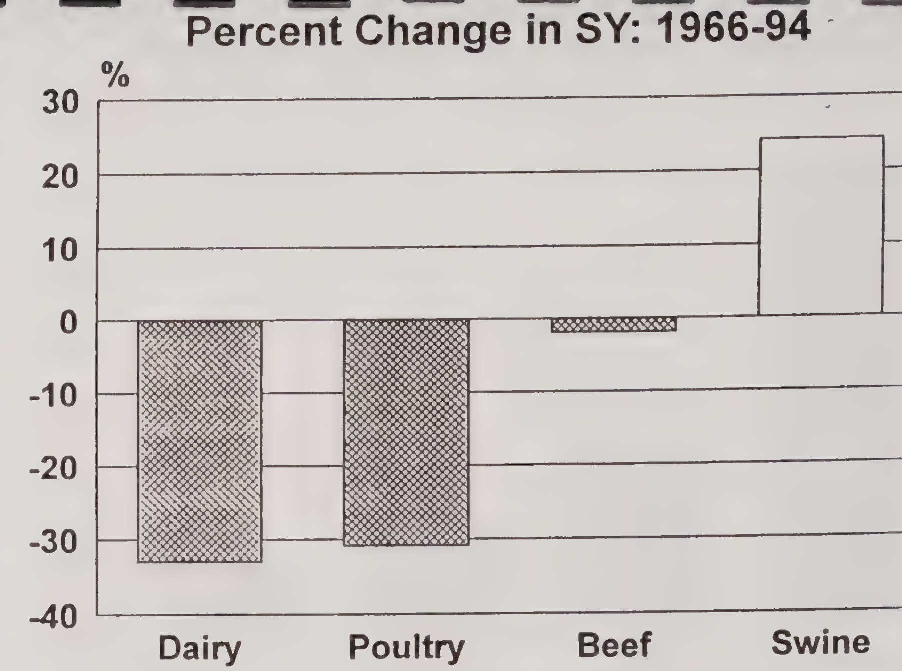
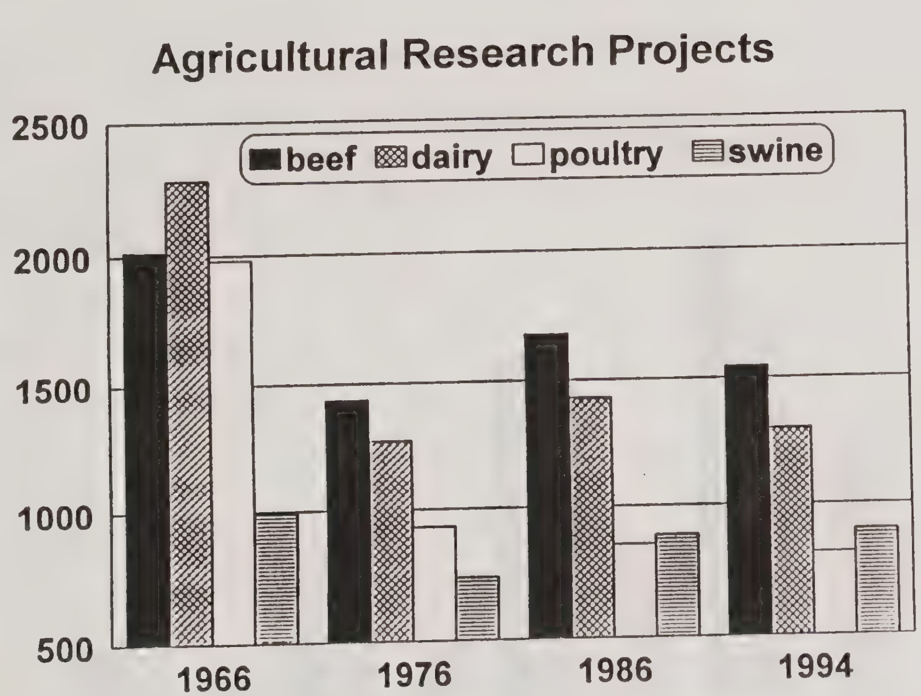


FIGURE 2



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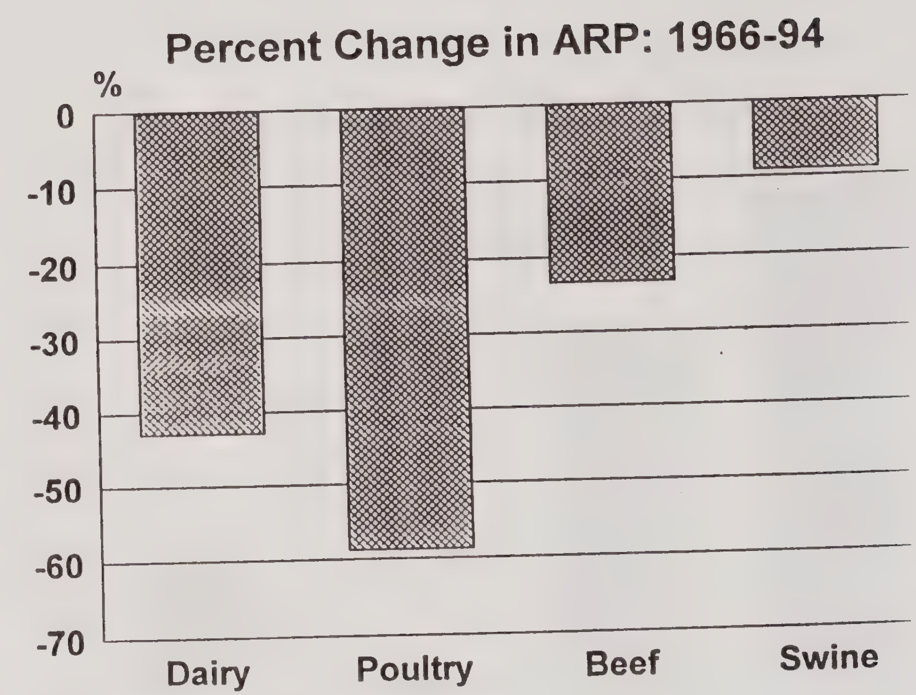

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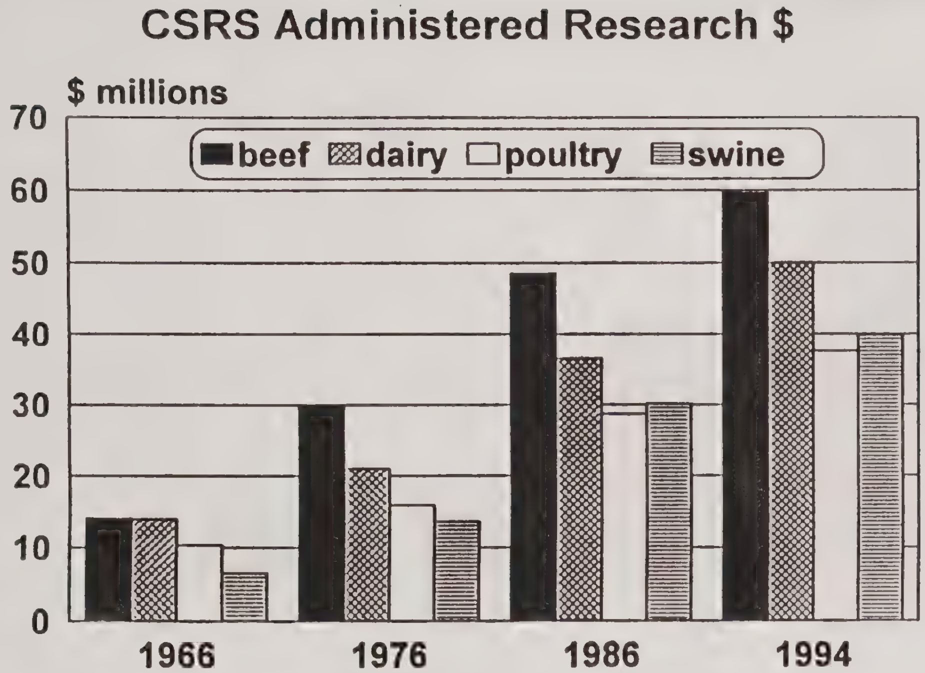

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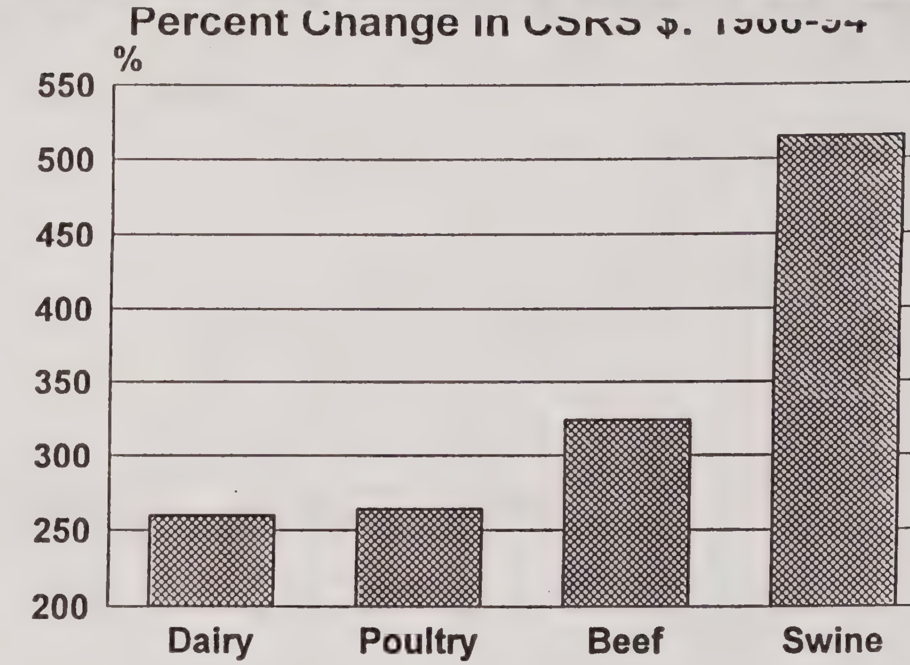

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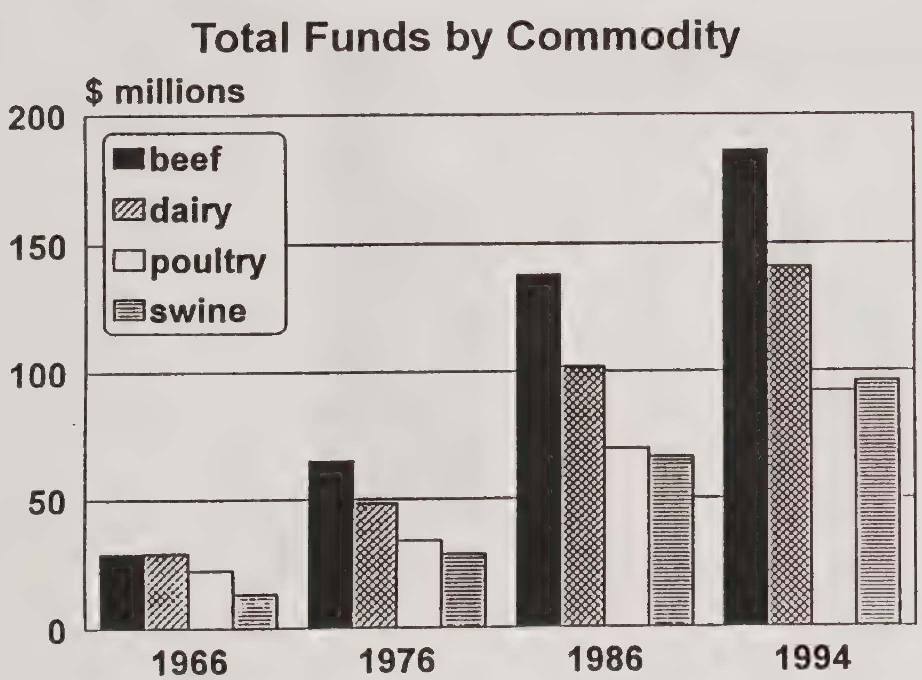

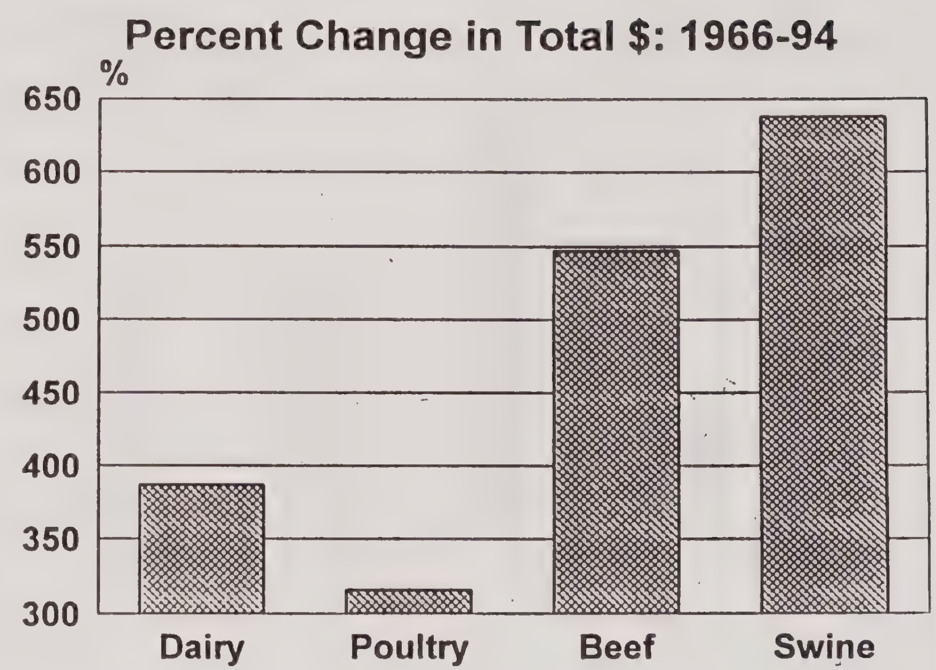

Relative Changes in World Meat Production

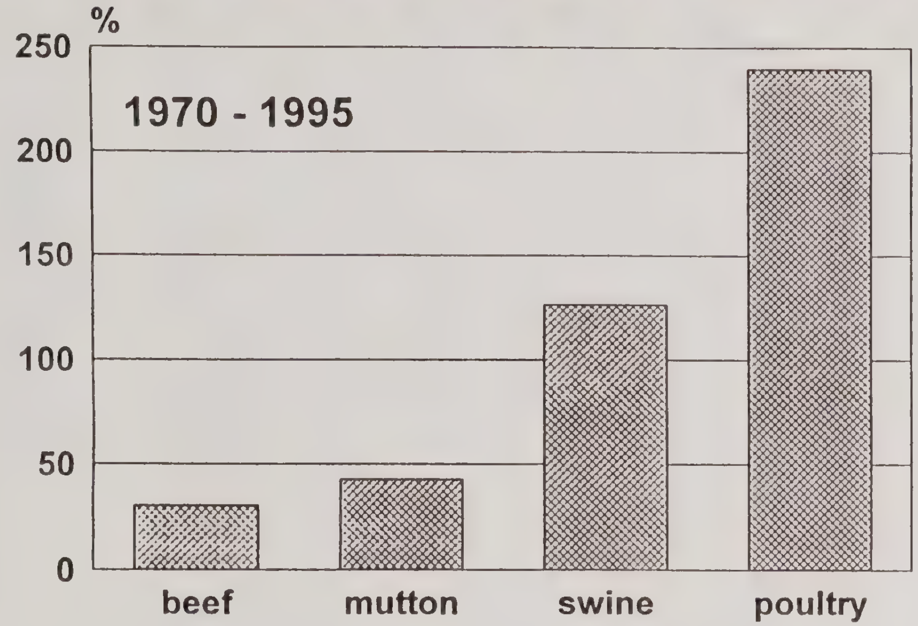

FIGURE 9

Relative Changes in USA Consumption

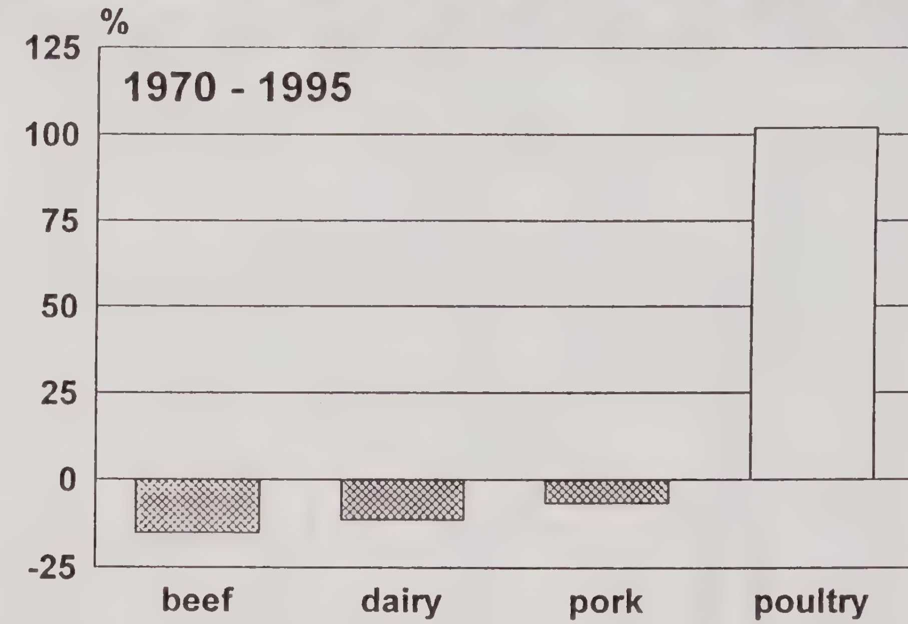

FIGURE 10

1995 USA Per Capita Consumption Rates

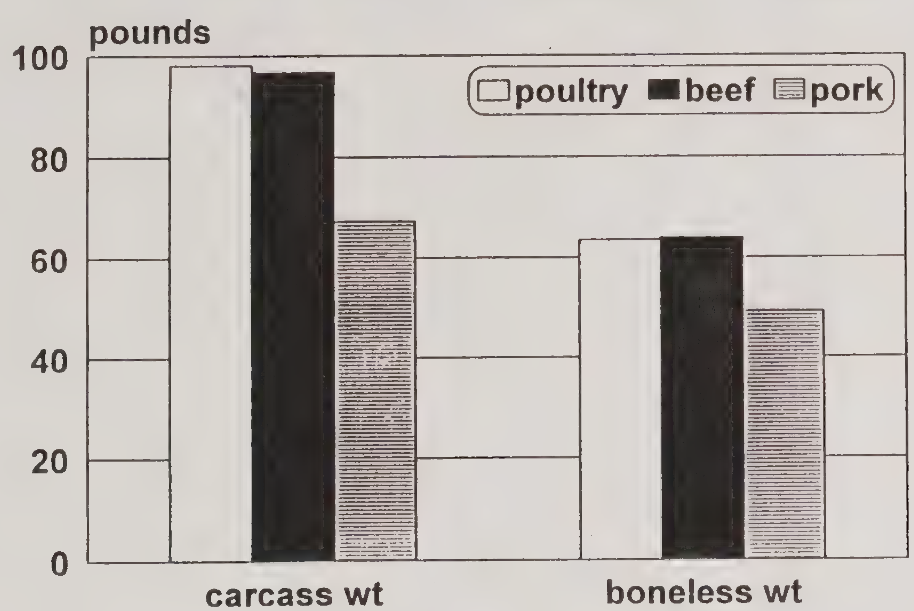

FIGURE 11

1995 US Commodity Values

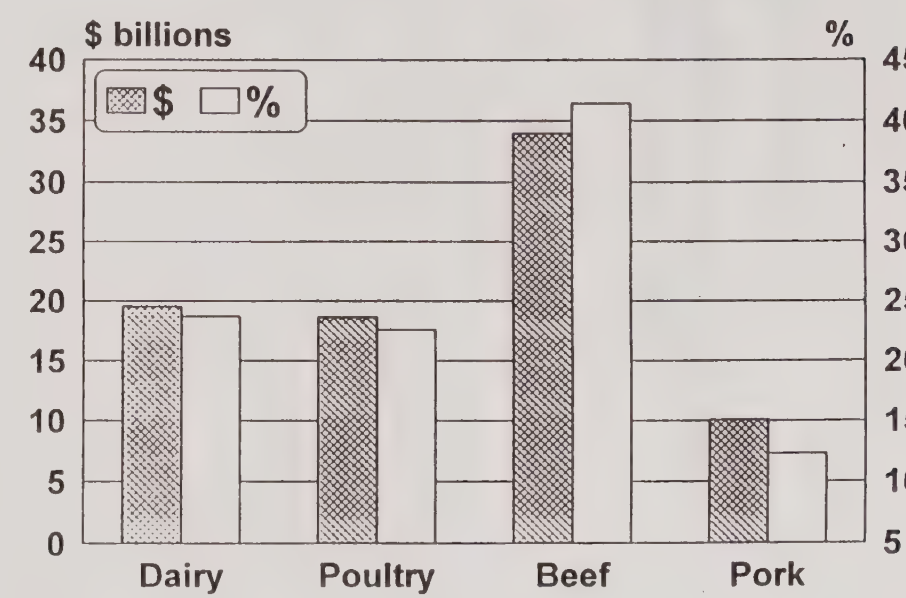

FIGURE 12

EDUCATION AND PRODUCTION

Educational Opportunities and Challenges in Poultry Science: Impact of Resource Allocation and Industry Needs

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ABSTRACT Because the number of Poultry Science departments in the U.S. has declined dramatically, and because scientist years and research funding for poultry, relative to other commodities, have also declined, a survey of poultry meat companies was conducted. Objectives of the survey were: to evaluate corporate concern over the status of Poultry Science departments, to categorize hiring patterns, to determine expectations for prerequisite skills of graduates, and to ascertain attitudes toward hiring of Associate-degreed students (A.S.). A two-page survey was distributed to corporate Vice Presidents or Directors of Human Resources of the 17 largest broiler and 10 largest turkey companies. When asked to gauge the difficulty they encountered in locating adequate numbers of Poultry Science graduates, 83% noted at least some difficulty. All respondents indicated concern over the loss of poultry programs in the U.S. and 44% noted "extreme" concern. There appears to be little resistance to hiring 2-yr A.S. degree graduates in Poultry Science. The relative scarcity of these programs is demonstrated by the fact that only one-third of the respondents had ever hired A.S. degree graduates. However, greater than 80% of the firms indicated they would hire these students. Finally, communication and business skills were more highly rated by human resources management than technical ability in Poultry Science. Given these results, academic programs must: develop curricula that reflect marketplace expectations, enhance the efficiency of resource utilization, embrace new technologies that provide novel methods for information delivery, and reassess cooperative linkages among industrial and governmental organizations.

(*Key words*: academic programs, curriculum, departmental status, resources)

1997 Poultry Science 76:938–943

INTRODUCTION

A paradox has developed over the past four decades regarding the declining emphasis on, and resources provided for, Poultry Science at land-grant universities and the dramatic expansion of the U.S. poultry industry. Attrition in the number of academic departments of Poultry Science has been one notable example of this decline (Figure 1). In 1960, there were 44 independent departments of Poultry Science in the U.S. (Sunde, 1969; Cook, 1988). Today, that number has been reduced by approximately 75%. During the 20-yr period from 1960 to 1979 alone, a total of 26 Poultry Science departments were either merged or eliminated (Cook, 1988). With greater than 87% of the nation's broilers being produced in the southeastern quadrant of the U.S. (South Atlantic and South Central USDA designated regions), it is not surprising that the remaining departments of Poultry Science are concentrated in this region (USDA, NASS, 1996). Clearly, economic forces alter an institution's mission and allocation of resources. In addition, federal and state agricultural policies influence programmatic shifts.

An apparent consequence of departmental mergers has been the de-emphasis of poultry, which subsequently led to a loss of poultry-oriented faculty positions (Table 1). From 1966 to 1995, the number of scientist years (SY) associated with poultry and dairy research declined by 31.8 (477.6 to 325.5) and 35.8% (595.7 to 382.3), respectively (USDA, CSRS [CSREES], 1966–95). It should be noted that whereas SY associated with dairy research have declined to a greater extent than poultry, the consumption of dairy products has not enjoyed the same dramatic increase as that observed in poultry. During the same period, SY associated with beef research exhibited relatively little change (–8.9%, 540.0 to 492.0) whereas SY dedicated to swine rose by 16.6% (232.7 to 271.4). What has occurred following most mergers may be described as a condensation of Poultry Science programs rather than a consolidation. Within less than a generation, faculty retirements and shifts in program focus typically have eroded the poultry component of combined departments. In 1966, SY associated with poultry represented 25.9% of total SY

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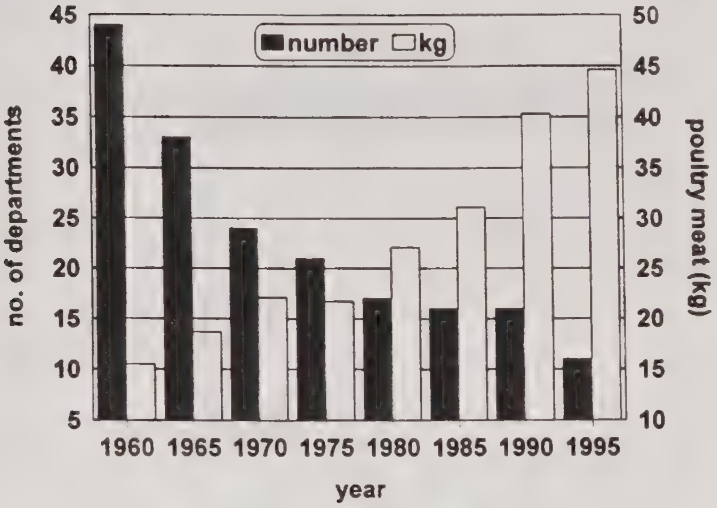


FIGURE 1. Comparison of trends in the number of U.S. Departments of Poultry Science and per capita poultry meat consumption.

dedicated to the four major animal commodities (Table 1). By 1995, that percentage had dropped to 22.1% of the total SY in these commodity areas.

In contrast to faculty positions and the number of Poultry Science departments, per capita poultry consumption in the U.S. has risen by approximately 185% since 1960 (Figure 1). Poultry meat consumption, broiler, other chicken, and turkey combined, now exceeds 44 kg per capita and represents the largest source of animal protein for U.S. consumers (Putnam and Allshouse, 1996). In 1960, U.S. production of broilers and turkeys was 1.79 billion and 84.5 million head, respectively (Madison and Perez, 1994). In 1995, production had increased to 7.33 billion broilers (> 300%) and 293 million turkeys (approximately 250%) (USDA, NASS, 1996).

The current national status of Poultry Science departments threatens their ability to train adequate numbers of undergraduate and graduate students to serve the poultry industry. With dwindling resources and a reduction in academic units, existing Poultry Science departments will need to re-examine their relationships with other academic units, state and federal agencies, and the private sector in order to effectively meet their academic, research, and extension missions. In an effort to evaluate the impact of the reduction in Poultry Science departments, faculty, and relative research funding on the poultry meat industry, a survey was utilized. The objectives of the survey were: to assess the level of corporate concern over the loss of Poultry Science departments nationally, to categorize corporate hiring needs and patterns, to determine expectations of prerequisite skills for Poultry Science graduates, and to ascertain attitudes toward the hiring of Associate-degree Poultry Science students. These data may assist in the development of policies dealing with a centralization of educational opportunities within disciplines such as Poultry Science, as well as course and curriculum content. To address these educational challenges, the potential of regionalization of programs, tuition waivers, distance learning, and the role of combined Animal and Poultry Science departments will be discussed.

MATERIALS AND METHODS

A two-page, self-administered survey instrument was developed and distributed to the nation's 17 largest

TABLE 1. Trends in U.S. agricultural research support by commodity[1]

Year	Commodity	Number of projects	Scientist years (SY)	CSRS administered funds[2]	Total research funds[3]
				($ millions)	
1966	Poultry	1,980	477.6	10.33	22.13
	Beef	2,014	540.0	14.06	28.73
	Dairy	2,279	595.7	13.92	28.90
	Swine	991	232.7	6.48	13.01
1976	Poultry	932	358.7	15.90	33.59
	Beef	1,437	558.6	30.06	65.05
	Dairy	1,274	438.7	21.01	48.19
	Swine	737	215.1	13.58	28.18
1986	Poultry	853	349.5	28.64	69.54
	Beef	1,680	582.5	48.58	137.94
	Dairy	1,431	444.0	36.54	101.86
	Swine	887	282.0	30.14	66.29
1995	Poultry	807	325.5	39.16	94.92
	Beef	1,427	492.0	58.20	184.37
	Dairy	1,263	382.3	47.37	141.75
	Swine	846	271.4	40.47	95.34

[1]USDA, CSRS (CSREES), FY 1966–95. Inventory of agricultural research. Table II-B, Washington, DC (1995 data courtesy of Dennis Unglesbee, CRIS).

[2]CSRS (CSREES) allocations, including overhead.

[3]USDA, other federal agencies, and state agencies' support, including overhead.

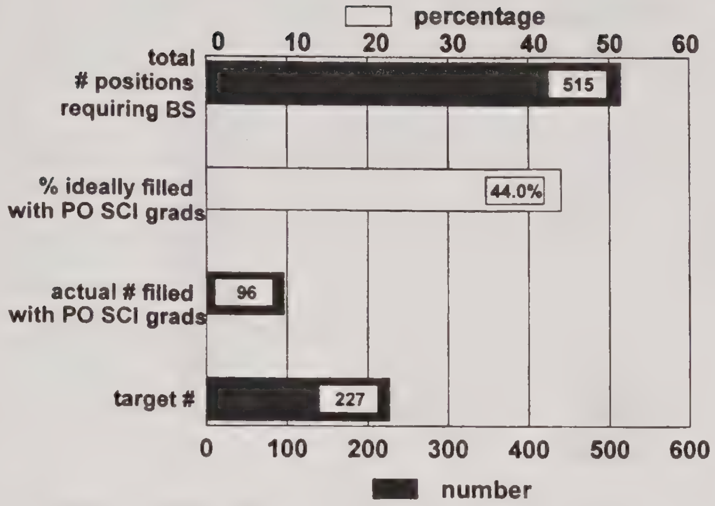


FIGURE 2. Annual hiring trends of major U.S. poultry companies. BS = Bachelor of Science, PO SCI = Poultry Science, grads = graduates.

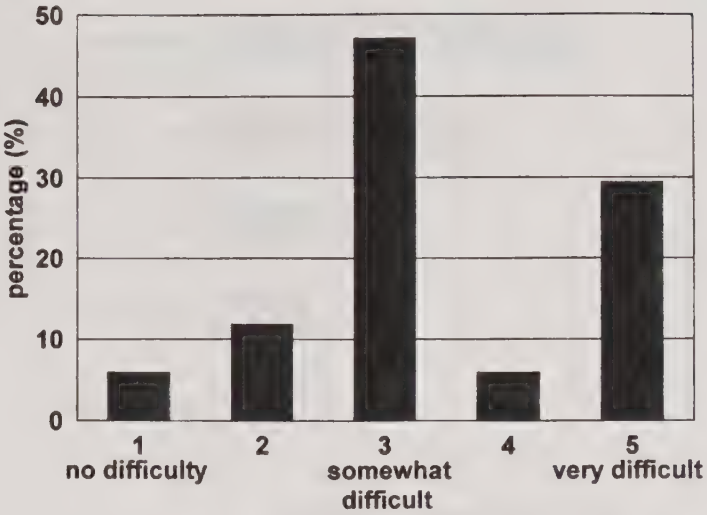


FIGURE 3. Level of difficulty encountered by major U.S. poultry companies in locating adequate numbers of Poultry Science graduates.

broiler and 10 largest turkey companies in December 1995 and responses were accepted through January 1996. Corporate Vice Presidents or Directors of Human Resources were the recipients of the survey. Some firms chose to redistribute the survey among their divisions or complexes before submitting a combined response. Eleven of the 17 broiler companies (64.7%), including the three largest integrators, responded to the survey. These companies represented more than 56% of the total U.S. broiler production in 1995. Eight turkey companies (80%), including the five largest companies, also responded. Greater than 55% of U.S. turkey production was associated with these firms. Data from the surveys are expressed as percentages of respondents unless otherwise noted. A copy of the survey form is available upon request.

RESULTS

Annual hiring trends of poultry meat companies are depicted in Figure 2. When asked to estimate the typical number of positions, filled annually within their organization, that would require a Bachelor of Science (B.S.) degree, a total of 515 potential employees were noted. Of the 515 projected new employees, poultry companies indicated that 44.0% would ideally be filled by individuals possessing a B.S. degree in Poultry Science. Therefore, a target of 227 new employees (515 × 0.44) would ideally be hired with those credentials. When the same firms were asked to estimate the typical number of individuals hired each year that had actually obtained such a degree, only 96 were noted. Based on these industry estimates, an annual shortfall of 131 Poultry Science graduates had occurred among the respondents. The true need for Poultry Science graduates, by the entire poultry industry, would obviously exceed those of the survey pool.

Figure 3 depicts the level of difficulty experienced by poultry integrators in locating adequate numbers of potential employees with a B.S. degree in Poultry Science. More than 82% of those surveyed indicated that they experienced moderate to extreme difficulty in hiring sufficient numbers of Poultry Science graduates. Less than 6% reported having no difficulty. Corporate concern associated with the loss of academic departments of Poultry Science is displayed in Figure 4. All respondents indicated that they were at least moderately concerned with these losses and approximately 44% were very concerned. Because of the limited availability of Poultry Science graduates with B.S. degrees, poultry integrators were also surveyed to ascertain hiring patterns relative to employees with an A.S. degree in Poultry Science. More than two-thirds of those companies surveyed had never hired individuals possessing an A.S. degree in Poultry Science (Figure 5). However, greater than 80% indicated that they would hire such individuals if they were available.

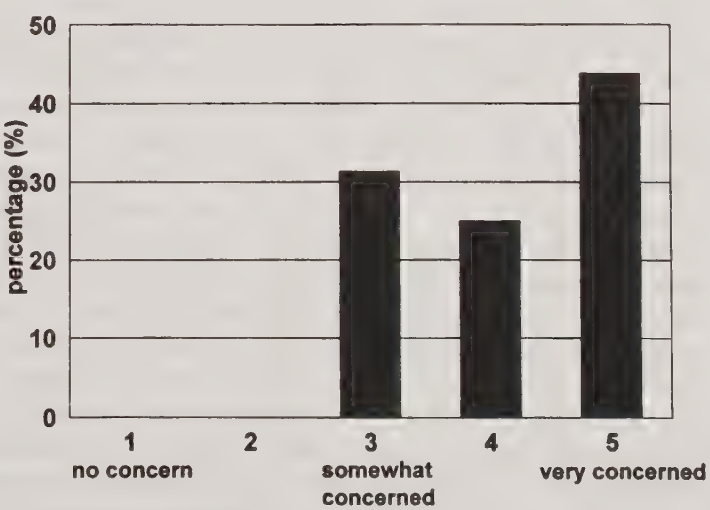


FIGURE 4. Level of concern expressed by major U.S. poultry companies over the loss of Departments of Poultry Science.

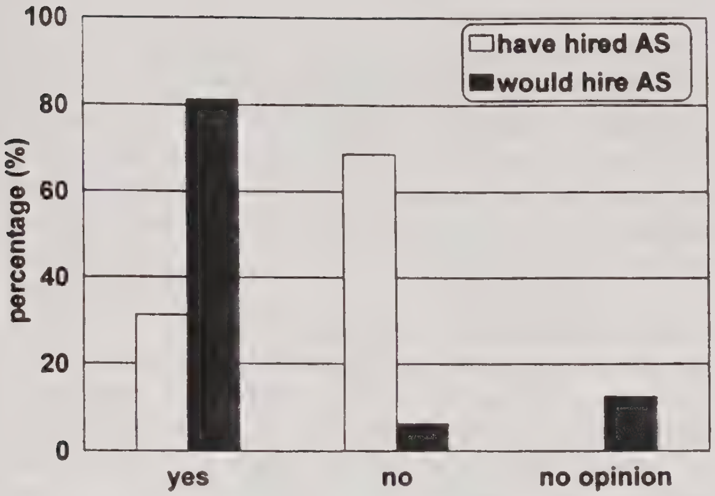


FIGURE 5. Hiring trends of major U.S. poultry companies with respect to Poultry Science graduates with an Associate of Science (AS) degree.

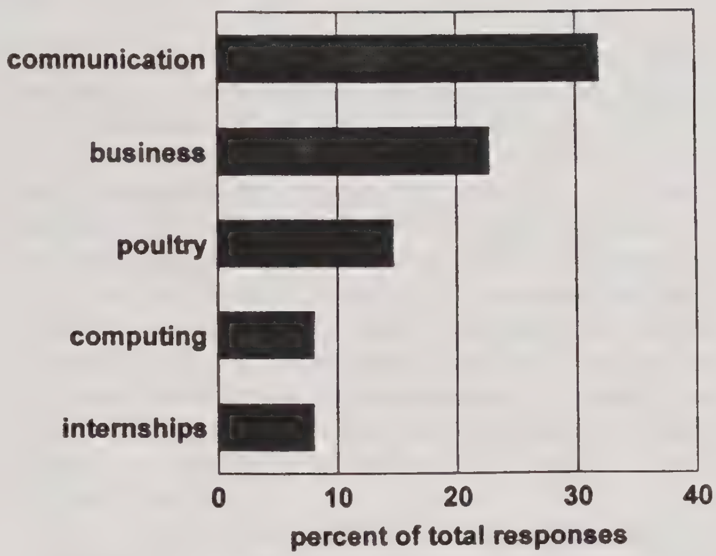


FIGURE 6. Rankings of requisite skills and experiences expected of recent Poultry Science graduates by human resources Directors or Vice Presidents of major U.S. poultry companies.

Finally, corporate Human Resources Directors and Vice Presidents were asked to prioritize the types of skills, training, or experiences that they would prefer recent Poultry Science graduates to possess. Respondents were permitted to give more than one answer. A total of 75 responses, within 10 major categories were provided. The five most frequently given response categories are displayed in Figure 6. A proficiency in communication, including interpersonal skills, presentation abilities (oral and written), conflict resolution, and bilingual competency, was most frequently mentioned. A general knowledge of business and economic principles was also highly rated. Skills directly associated with the general discipline areas of Poultry Science ranked third. Computing skills and exposure to "real world" experiences in the poultry industry (i.e., internships) were equally ranked as the fourth most frequent responses.

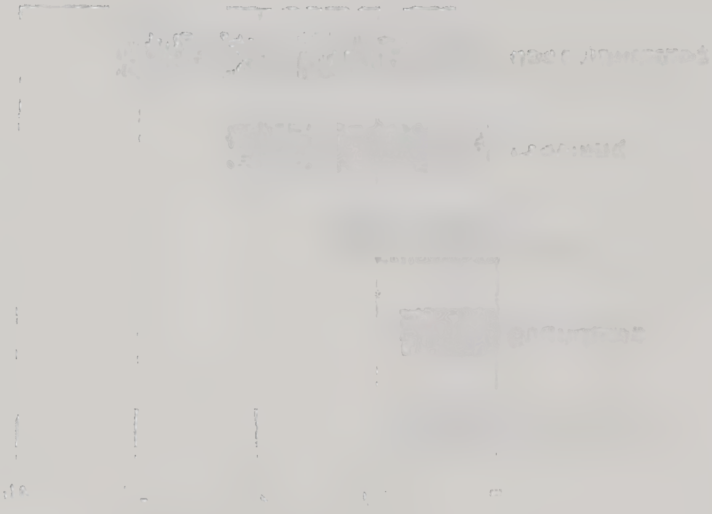
DISCUSSION

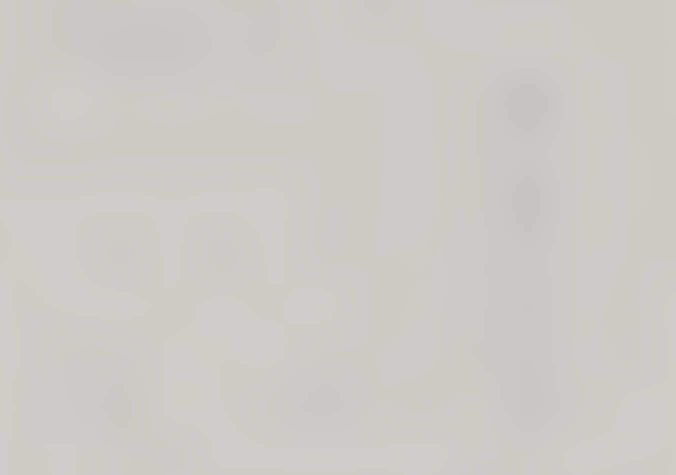
Educational challenges facing Poultry Science may be categorized in two major areas: declining resources, characterized by decreasing numbers of academic units and poultry-related scientists and relatively poorer funding from federal and state agencies, and the evolving nature of requisite skills required of the successful manager in the modern poultry industry. If we are to effectively meet these challenges and serve the poultry industry in the future, we will be required to utilize resources more efficiently, to embrace new technologies that provide novel methods for information delivery, and reassess interrelationships among academic, industrial, and governmental organizations.

A fundamental element of any organization is the maintenance of a "critical mass". It is probably unrealistic to anticipate the formation of new departments of Poultry Science in the U.S. Therefore, we will have to operate in a environment of fewer than a dozen departments in the U.S. The apparent diminished importance of poultry in national agricultural priorities may have its roots in policies and attitudes of more than 100 yr ago. In a report to the Board of the New York Agricultural Experiment Station, Director Peter Collier wrote these words in 1889 (cited in Termohlen, 1967):

> It is not a little strange that in the establishment of agricultural experiment stations, the poultry industry should have been so utterly ignored. Were it an unimportant branch of agriculture, were the value of poultry products comparatively small, it would be different, but as everyone knows their value stands second to scarcely any product on the farm...

In some aspects, Collier's statement could have easily been made in a contemporary setting. Since 1966, the number of poultry-related research projects supported by CSRS have declined by 59% [USDA, CSRS (CSREES), 1966–95]. During the same period, declines in the number of research projects that focused on beef and pork were only 29 and 15%, respectively. As U.S. poultry production became more concentrated regionally, Experiment Stations made adjustments in program emphases to reflect the relative increase or decrease of poultry in their state. This process developed over several years. Because of tenure, local and national political forces, and other factors, it is difficult to make rapid program shifts; i.e., downsizing one unit to build another. It appears, however, that even among states with a rapidly expanding poultry industry, additional positions in Poultry Science have been allocated infrequently. A number of instances exist in which poultry production has doubled or tripled in a state and the number of Poultry Science personnel and support has remained relatively stagnant or declined. For example, in three southeastern states where poultry represents 30 to 57% of total farm receipts, combined research





expenditures for poultry equaled $10.1 million in 1994 [USDA, CSRS (CSREES), 1994]. In contrast, roughly $15 million was allocated for beef and dairy research in these states despite their smaller economic impact. In an extreme example, poultry revenues in one state exceeded those of beef and dairy combined by approximately $1.5 billion, yet poultry received 36% less total research funds.

In 1995, total funds allocated for beef ($184 million) were approximately twofold greater than funds appropriated for poultry ($95 million). Because most faculty in Colleges of Agriculture at land-grant institutions have dual appointments, resources allocated for poultry research have direct impacts on academic programs. It is not difficult to envision that the loss of research-oriented positions in Poultry Science inevitably results in a concomitant decline in teaching full time equivalents (FTE).

As the number of Poultry Science departments and faculty decline, the remaining academic units and faculty clusters in merged departments will need to develop greater cooperation. Although research initiatives have frequently crossed institutional boundaries with collaborative projects, academic programs have, by-in-large, remained somewhat provincial and isolated within individual campuses. The continued erosion of Poultry Science programs remains a distinct possibility given the current legislative climate at both the state and federal levels. One alternative to address this crisis is represented by the model established by the Midwest Poultry Science Undergraduate Center of Excellence. Based at the University of Wisconsin, the Center provides undergraduate education in Poultry Science by offering summer course work at the Madison campus. Students from the Center's member institutions pay in-state tuition through a tuition reciprocity agreement. Institutions with limited numbers of poultry faculty may want to consider such an option. In many cases, legislative action is required in order to establish tuition reciprocity for out-of-state students. Therefore, creating an academic center that mimics the Midwest model would require a significant amount of coordination and commitment. Some poultry faculty and administrators are opposed to efforts for regionalization because it is perceived as invasive and potentially undermining local efforts. Administrators must evaluate their faculty's expertise and make decisions based upon the best interest of students desiring an undergraduate Poultry Science degree program.

The development of media delivery systems, frequently referred to collectively as "distance learning", has the potential to ameliorate some of the problems associated with the loss of specialized expertise (i.e., poultry) at an institution. For example, unique courses could be developed for distribution on the Internet that could provide students at remote sites access to information that they would not receive otherwise. This would allow merged departments with only a small number of poultry-based FTE to provide broad-based introductory course work in the area of Poultry Science. If an institution did not have the requisite expertise "in-house" to teach more advanced courses, poultry nutrition, physiology, or diseases for example, then these courses could be provided electronically. The need for the administration of laboratories would still exist and could be met locally or during an intensive summer experience at another institution. Although the quality of learning via the Internet is somewhat ill-defined at this time, it does provide one alternative to meeting the needs of those students who have an interest in Poultry Science and whose home institution is unable to fully address those needs.

The second major challenge facing academic programs of Poultry Science reflects the changing skills that its graduates must possess to be successful. During the past three decades, a fundamental shift has occurred in the types of positions typically filled by graduates of Poultry Science departments. In the past, a majority of graduates were hired to fill positions in live production. Today, the greatest number of employment opportunities are in the processing plant. Instructors tend to teach subject areas in which they are the most comfortable and have the largest knowledge base. This contributes to an apparent emphasis on live production found in many Poultry Science curricula and limited exposure to processing (Waldroup, 1994). For many land-grant institutions, course work in poultry processing is housed in the Food or Meat Sciences departments. Not only has there been a shift toward greater opportunities in processing, but also an apparent change in the set of priorities used to evaluate prospective employees. Some have suggested that the poultry industry now places less emphasis on a strong technical foundation in Poultry Science and greater importance on "people" skills. A cursory evaluation of the present survey information would appear to support that position. The implications of such an attitude reinforce the necessity of frequent curriculum reviews by Poultry Science departments. Technical competence alone does not insure the success of newly hired management trainees. Suggestions to enhance the business acumen of Poultry Science graduates is not a recent development. Pescatore (1988), almost a decade ago, noted that more business courses should be required of Poultry Science majors.

Poultry integrators and processors have been forced to obtain many of their employees from non-Poultry Science backgrounds (Pardue, 1991). Figure 2 depicts the degree to which poultry companies have had to tap other pools of applicants to meet their staffing requirements. According to the present study, major poultry integrators and processors would ideally prefer to hire more Poultry Science graduates. However, it is apparent that expectations for those graduates will require that they possess a more diverse combination of skills. Opportunities do exist for students completing an A.S. degree in Poultry Science. Limited numbers of programams

and subsequently low student numbers would explain why approximately two-thirds of survey respondents had never hired an A.S. degree Poultry Science graduate. More than 80% of those surveyed indicated that they would hire A.S. graduates.

If Poultry or combined Animal/Poultry Science departments are to receive additional poultry-oriented faculty, they will probably do so at the expense of some other commodity. Bringing about such a shift will not be easy. Many of these other commodities have well-funded and well-organized political action groups and lobbyists. Removal of faculty support from even a commodity of little economic importance will be met with resistance. Many departments will struggle to maintain current levels of faculty and resources. For many institutions, the decade of the 1990s has been one of downsizing. Many Experiment Station directors have had little opportunity to make adjustments in program emphasis given the nature of recent federal funding. In contrast to their ability to obtain additional positions, Poultry Science departments do have greater control over their course and curriculum content. If the industry's criteria for hiring has shifted to emphasize "people" and business skills, then an opportunity exists for merged departments to develop specialized programs that would not require the same number of poultry-related courses typically offered at departments of Poultry Science. If an "appropriate" level of poultry instruction could be maintained in these merged departments, one strategy could be to develop more business-oriented students who have an appreciation for poultry. It is in these areas that we can best assure the poultry industry of the relevance of our graduates. A failure to do so will erode political support for poultry programs and negatively affect departmental/program survival.

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